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SUR L'APPLICATION DE LA SCIENCE ET DE LA TECHNIQUE
DANS L'INTÉRÊT DES RÉGIONS PEU DÉVELOPPÉES

Point de l'ordre du jour : A. 3. 3. 3

Belgique

EMMAGASINEMENT SOUTERRAIN ET RECONSTITUTION DES NAPPES D'EAU SOUTERRAINES

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Internationale d'Hydrologie Scientifique

Les mémoires rédigés à l'intention de la Conférence des Nations Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées sont des documents de travail. Ils sont publiés tels qu'ils ont été présentés et les assertions et opinions qu'ils contiennent sont celles de leurs auteurs.

NOTES

1. Les mémoires choisis pour être présentés en séance générale pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

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EMMAGASINEMENT SOUTERRAIN ET RECONSTITUTION DES NAPPES D'EAU SOUTERRAINES

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1. Introduction.-

L'exploitation de plus en plus généralisée et profonde des nappes aquifères dans les pays à civilisation ancienne a conduit les ingénieurs et hydrologues à des recherches et à des essais pour arriver à emmagasiner souterrainement des eaux de surface et pour reconstituer des nappes ayant tendance à s'épuiser, du fait de leur exploitation intensive. Dans les pays neufs, le problème se pose bien souvent de façon plus dramatique du fait de l'insuffisance des ressources en eau souterraine pour arriver à une mise en exploitation suffisante de l'agriculture, de l'industrie du pays et même pour leur donner une hygiène suffisante.

L'évaporation généralement très réduite caractérisant l'emmagasinement souterrain lui donne sur les réservoirs de surface un avantage particulièrement marqué là où cette évaporation peut porter sur des fractions non négligeables des masses d'eau emmagasinées, ce qui est précisément souvent le cas pour les pays en zones arides ou semi-arides D'autre part, les sites pour la construction de barrages réservoirs peuvent être rares dans certains régions et la sédimentation peut en réduire rapidement la capacité utile. Par contre, la disposition géologique d'une région peut offrir des couches perméables disposées de façon à offrir de larges possibilités d'emmagasinement souterrain d'eau.

2. Antécédents.-

L'idée d'une régulation dans le soutirage des eaux souterraines est d'ailleurs assez ancienne et bien des captages de l'Europe de l'Ouest, construits il y a près de cent ans, possèdent des galeries avec "serrements".

Ces serrements établis à la traversée d'une couche peu ou pas perméable permettent d'isoler par leur fermeture les parties des galeries à l'amont des serrements, de sorte que dans les massifs alimentant ces parties isolées, la nappe tend à reprendre son état naturel d'avant le captage, réalisant des réserves que l'ouverture des serrements rendra disponible à volonté. Il s'agit là d'un cas assez particulier plutôt cité à titre historique. Il y a simplement dans ce cas régularisation des apports naturels pour les adapter à la consommation.

3. Reconstitution des nappes.

3.1 - Solutions possibles. - Le problème s'est évidemment élargi et il a fallu non seulement régulariser les ressources mais les augmenter par des moyens artificiels. On a pu envisager une reconstitution directe des nappes en les alimentant par des eaux de surface qu'on amène soit à recouvrir des champs d'épandage, soit à s'infiltrer dans les rigoles, soit à se perdre dans les puits absorbants. Et à côté de cette réalimentation directe, on a considéré une reconstitution indirecte (ou induite comme l'ont appelée les Américains) en créant des dispositifs qui captent non seulement l'eau propre de la nappe, mais en provoquant son rabattement, amènent l'eau de rivières ou de lacs voisins à pénétrer dans la nappe et à assurer sa réalimentation continue.

3.2 - Recharge indirecte. - Cette recharge indirecte est utilisée par la plupart des installations de captage établies dans les sédiments (sables et graviers) de plaines alluviales à proximité plus ou moins grande de la rivière suivant le degré de perméabilité, à l'aide de puits ou de galeries.
La méthode est ancienne et ces captages constituent une des sources les plus abondantes et souvent les plus économiques. Cette aisance d'obtention d'une eau souvent propre à de multiples usages jointe à la navigabilité de la rivière toute proche a souvent attiré l'implantation de concentrations industrielles puissantes (Rhin, Meuse, Ohio)
Les débits que peuvent donner ces captages dépendent de la perméabilité, de la distance de la rivière et de la possibilité d'existence de dépôts dans le lit de la rivière, dépôts qui pourraient créer un obstacle à la filtration. Le balayage de ces dépôts par les crues est un élément favorable. Souvent les diverses couches constituant le plaine alluviale n'ont pas la même perméabilité et il arrive fréquemment que les couches inférieures, déposées par une rivière plus rapide, donnent de meilleurs débits que celles du dessus. La qualité de l'eau est évidemment influencée par celle de la rivière, l'eau pompée étant un mélange de cette dernière avec les eaux souterraines alimentant aussi les dépôts de la plaine alluviale. La méthode comme on l'a vu est ancienne, mais elle a encore attiré l'attention dans les derniers temps par l'utilisation de puits à drains horizontaux dont les branchements peuvent même s'étendre sous la rivière, donnant des possibilités de débits considérables et de qualités variant quasi à volonté par la manoeuvre d'admission des différents drains dont les eaux sont ou bien en provenance quasi directe de la rivière ou bien s'enfoncent dans la nappe initiale.

3.3. - Recharge directe.

3.3.1 - Principes

La recharge directe peut être d'application plus générale. Dans la reconstitution directe des nappes, la recharge peut d'ailleurs se faire de multiples façons qui donnent lieu à autant de systèmes différents. Il y a de toute façon toujours une infiltration d'eau, en général superficielle; mais cette infiltration peut se faire par un épandage analogue à une inondation (flooding) par des ravines et tranchées, à l'aide de bassins, en aménagement le lit de cours d'eau, par des puits absorbants, par des fouilles plus ou moins profondes.

Le tableau ci-après, emprunté à Mullnix, donne une idée de la répartition de ces divers procédés, fin 1957, dans une des régions du monde où la recharge a été largement appliquée, la Californie.

Méthode	Pourcentage sur l'ensemble des réalisations.	Pourcentage du volume d'eau épanchée en 46 ans.
Bassins	54	45
Modification du lit	15	37
Tranchées	8	17
Puits absorbants	12	1
Dépressions	7	1
Epandage (flooding)	4	1

3.3.2. - Infiltration et Percolation.

A la base de ces méthodes directes se trouvent évidemment les possibilités d'infiltration, à l'entrée de l'eau dans la couche supérieure du sol et de percolation, à travers les couches sous-jacentes jusqu'à la nappe. Infiltration et percolation interviennent toutes deux pour influencer la recharge. Le taux d'infiltration est par définition la vitesse de l'eau pénétrant dans le sol et il s'exprime en centimètres par jour (ou en pieds par jour).

On a parfois essayé d'établir une relation entre la texture du sol et le taux d'infiltration et c'est ainsi que Richter estime que les sols à texture grossière donnent des taux d'infiltration compris entre 1,6 et 10 pieds par jour avec une moyenne de 4,2. Pour les textures moyennes, le taux d'infiltration varie de 1,7 à 3,6 pieds par jour, avec une moyenne de 2,2 tandis que les sols à texture fine donnent moins de 1,0 pied par jour avec une moyenne de 0,46. Il faut cependant éviter de donner à semblable relation une valeur trop absolue ; d'autres éléments que la texture peuvent intervenir comme on le verra : par exemple, le couvert végétal, la stabilité de la structure, la présence de matières en suspension dans l'eau, etc.

Il n'en est pas moins vrai qu'il y a tout avantage à choisir des terrains de recharge à texture grossière et à ce point de vue, les cônes de déjection qui se sont formés aux débouchés dans les vallées larges des affluents plus ou moins torrentiels du cours d'eau principal, constituent souvent des endroits d'élection pour l'établissement de recharge, les terrains de captage se plaçant à l'aval des zones où se fait l'enrichissement.

En dépit de ces choix, qui ne sont d'ailleurs pas toujours possibles, la nécessité de traitements tant pour le sol que pour l'eau se manifestera dans bien des circonstances.
Une étude du sol surtout au point de vue de la perméabilité des couches constituantes ainsi que pour se rendre compte de la capacité d'emmagasinement offerte par la couche à recharger est par conséquent d'absolue nécessité pour l'établissement de projets de recharge. Des sondages avec examen d'échantillons non remaniés en laboratoire, permettront de repérer l'extension des couches de faible perméabilité et les volumes offerts à la recharge à l'aide de coupes longitudinales et transversales. L'étude du sol doit aller de pair avec celle de l'eau de recharge dont on doit connaître les variations de teneurs en sédiments et les propriétés physiques et chimiques.

3.3.3. - Traitements du sol et de l'eau pouvant accroître la vitesse de recharge.

L'accroissement de cette vitesse de filtration a pour effet de permettre une réduction de la surface d'infiltration et par suite de l'étendue enlevée à la culture.

3.3.3.1. - Si le sol possède à la fois de bonnes qualités d'infiltration et de percolation, (cas des cônes de débris signalés ci-dessus), le problème consistera surtout à lui garder ces précieuses propriétés en empêchant son colmatage. Dans ce cas c'est donc sur les eaux qu'il faudra porter son attention. Les eaux chargées de sédiments en suspension devront donc pouvoir être déviées par des by-pass.Une certaine teneur de matières en suspension peut cependant être tolérée lorsque la surface d'épandage ou le bassin sont "protégés" par une végétation assez dense (Bermuda grass des Américains, par exemple). Dans pareils cas, des teneurs de matières en suspension atteignant jusque 600 p.p.m. ont pu être tolérées pendant de courtes périodes. Les couvertures herbeuses ont quasi quadruplé le taux d'infiltration pour une durée supérieure à 5 ans.

Des bassins, des fossés, ou l'épandage en surface pourront être utilisés avec ces sols favorables tant à l'infiltration qu'à la percolation en profondeur. Les bassins sont réalisés par la construction de diguettes en matériaux non érodibles (des fragments de roches maintenus par des fils de fer tissés, par exemple). La hauteur de ces diguettes est suffisante pour assurer la couverture du sol par l'eau d'une diguette jusqu'au pied de celle qui se trouve plus à l'amont. L'alimentation se fait par le ou les bassins d'amont, l'eau passant d'un bassin à l'autre par déversement sur les diguettes. Lorsque l'on utilise des fossés ou petits canaux pour l'infiltration de l'eau, on leur donne peu de profondeur, un fond plat et une entredistance assez faible. Leur tracé dépend de la topographie du terrain et leur pente doit empêcher tant le dépôt de matériaux que l'érosion du sol.

L'inconvénient du procédé par canaux ou fossés d'infiltration est de réduire la surface d'infiltration à 10 ou 12 % de la surface totale des terrains utilisés, alors que dans la méthode par bassin ce pourcentage est de 75 à 80 %. Cette méthode par bassins est d'application particulièrement aisée dans les plaines alluviales. Elle peut d'ailleurs s'étendre à des lits abandonnés et s'appliquer concurremment avec l'infiltration provenant du lit de la rivière.

Enfin, dans la méthode par épandage en surface (flooding), on fait passer l'eau sous faible épaisseur sur toute l'étendue réservée à l'infiltration, en assurant un contrôle suffisant pour que l'écoulement ne se concentre pas en des endroits privilègiés par érosion du sol. Cette érosion doit être évitée à tout prix afin de laisser à la surface du sol sa texture primitive.

Si les eaux utilisées pour la recharge sont toujours quelque peu chargées, on pourra les obliger à une certaine sédimentation dans des bassins spécialement réservés à cet usage à l'amont de la zone d'épandage. On pourra d'ailleurs y ajouter des substances floculantes. Cette préparation peut d'ailleurs s'appliquer si on utilise d'autres procédés de recharge comme les puits d'infiltration ou les fouilles.

3.3.3.2. - Lorsque le sol possède une bonne capacité de percolation mais que sa surface ne permet qu'une infiltration trop réduite, il y a lieu d'améliorer les caractéristiques de l'eau et de la surface du sol, tout en utilisant certaines pratiques d'exploitation. De nombreuses recherches en Californie ont montré que l'infiltration peut être notablement augmentée (quatre fois et plus) et stabilisée en incorporant à la couche supérieure (sur 5 cm environ) des substances organiques.

De très heureux résultats ont notamment été obtenus en utilisant des déchets de plantations de coton (tiges, feuilles, semences, des restes de fibres - cotton gin trash des Américains).

Les essais montrent que ces substances produisent leur action maximum lorsque le sol traité est submergé pendant 8 semaines. Leur influence n'est pas complètement élucidée, mais il semble bien qu'elle s'explique par une action microbienne améliorant la texture du sol, superficiel. L'action favorable d'une couverture par une végétation herbeuse a été signalée. Certains produits chimiques produisent une action du même genre (voir Schiff). On notera aussi que tout ce qui rend le sol plus compact, réduit l'infiltration : ceci est particulièrement à prendre en considération dans les travaux d'aménagement et d'entretien. On a également essayé de traiter l'eau amenée en y ajoutant du gypse ou de l'acide sulfurique. L'amélioration ne fut pas significative. Par contre des additions de sulfate ferrique ont donné de meilleurs résultats.

3.3.3.3. - Il reste une troisième éventualité : l'infiltration est bonne, mais la percolation est insuffisante. Les résultats donnés par l'étude des sols sont particulièrement importants dans ce cas, pour déceler les horizons causes de la mauvaise percolation. L'emploi de méthodes d'injection utilisant des fouilles ouvertes, des tranchées plus ou moins profondes, peuvent donner de sérieuses améliorations en éliminant les couches hydrauliquement résistantes et en augmentant la charge par l'eau de remplissage de la dépression créée. On a essayé de remplir ces fouilles ou d'en recouvrir le fond et les parois de matériaux graveleux constituant des filtres. (voir paragraphe 3.3.6) D'autre part, dans ce cas, de véritables puits et notamment des puits tubés, perforés latéralement peuvent être utilisée comme puits absorbants. Quel que soit le système utilisé, si l'eau disponible pour la recharge est chargée de sédiments, il faudra évidemment la soumettre à une décantation, dans des bassins et même l'accélérer par l'ajoute de floculants comme on l'a déjà signalé plus haut.

Un des inconvénients de l'emploi de s puits absorbants est la réduction de leur faculté d'absorption avec le temps, non seulement sous l'action du colmatage dont il vient d'être question, mais plus encore par suite de la formation de pellicules ou films, vraisemblablement dus aux algues ou aux bactéries. On a pu remédier à cet inconvénient en stérilisant l'eau de recharge à l'aide de sulfate de cuivre, d'hypochloride de calcium , de "chlorine" etc. On a aussi pu rétablir le pouvoir absorbant de ces puits en inversant leur mode d'action et en les transformant temporairement en puits ordinaires dont on tire un certain débit, soit encore en les entourant de gravier dans lequel on injecte de l'eau sous pression par un tube perforé placé à l'extérieur du puits de recharge.

A remarquer encore que les formules simples déduites de la loi de Darcy (et de l'hypothèse de Dupuit) peuvent donner des indications quantatives si l'étude préparatoire du terrain et notamment la détermination de son coefficient de perméabilité a été préalablement faite en laboratoire.

On peut encore observer que dans le cas présent (taux de percolation profonde insuffisant), si on est obligé par une raison ou l'autre de ne pas utiliser des dispositifs profonds (puits ou cavités naturelles ou non), il est indiqué de limiter l'infiltration à une partie de la surface, par exemple à des bandes de terrain ou à des fossés; ainsi l'espace entre ces bandes reste utilisable pour la culture.

On signalera enfin que même des nappes captives ont pu être rechargées à l'aide de puits traversant les couches imperméables du toit pour déboucher dans la couche porteuse perméable.

3.3.4. - Pratiques opérationnelles:-

Il a été question au paragraphe 3.3.3.2. de certaines pratiques d'opérations qui peuvent améliorer l'infiltration. Il a été notamment observé que l'assèchement des surfaces d'épandage, fossés, bassins, etc. leur permet de retrouver leur capacité d'infiltration, surtout si les sols en question contiennent des matières organiques. Il en résulte que par des alternatives de fonctionnement et de repos sans immersion ces surfaces présenteront toujours des taux d'infiltration élevés. La longueur optima des pauses doit se déterminer par l'usage. Un système de ce type a notamment été indiqué par Schiff.

3.3.5. - Procédés pour améliorer le taux d'infiltration.-

On a dit un mot de la possibilité d'augmenter le taux d'infiltration, à l'aide de filtres. Schiff et Suter ont fait des essais dans ce sens. Les résultats de Schiff montrent qu'on peut au moins doubler le taux d'infiltration en repandant à la surface d'infiltration du sable tamisé dont les grains ont de 0,5 à 1 mm de diamètre. Des grains de gravier de 3 à 6 mm lui ont par contre donné peu d'amélioration, tandis que des débris de roches aux angles vifs ayant ces dernieres dimensions avaient une action comparable à celle des sables cités. Suter à Peoria a cependant obtenu des résultats intéressants avec des graviers aux éléments aussi volumineux. Ces résultats justifient des réalisations avec puits remplis de gravier établis au fond de tranchées et alimentés par des drains eux-mêmes recouverts de gravier également au fond de tranchées.

3.3.6. - Quelques constatations.-

Le taux de recharge n'est pas influencé par la profondeur à laquelle se trouve la surface de la nappe, sauf évidemment lorsque cette nappe affleure. Il y a donc intérêt à choisir pour la recharge, des nappes profondes. Il a été constaté que la hausse de la température de l'eau augmente le taux d'infiltration. Il fallait s'y attendre : tant l'infiltration que la percolation, sont réglées par la loi de Darcy : d'après celle-ci, la vitesse d'infiltration ou de percolation est proportionnelle au coefficient de perméabilité qui est lui-même influencé par la viscosité de l'eau, fonction à son tour de la température.

3.3.7. - Recharge par l'irrigation.-

Les eaux d'irrigation ne sont évidemment pas utilisées complètement par la végétation. Une partie de ces eaux percole vers la nappe et la recharge. Dans certaines régions, le gonflement de la nappe dû à l'irrigation peut atteindre des proportions réellement considérables. C'est ainsi que Nace signale notamment l'exemple de la Snake River Plain de l'Idaho. Sur la rive Sud de la rivière, vers Tivin Falls, la nappe s'y trouvait, à l'origine à grande profondeur, mais les irrigations sur une surface de plus de 80.000 Ha ont fait monter son niveau de 70 à 100 m et plus, en 25 ans, l'emmagasinement portant sur plusieurs centaines de millions de m3.
Des applications de ce genre méritent un intérêt tout particulier. Certaines cultures (luzerne, coton) supportent une irrigation surabondante. De plus , l'irrigation pourrait être continuée, quasi sans dépenses nouvelles, au cours des mois sans culture. On peut arriver de cette façon à une recharge qui serait un "sous-produit" très intéressant de l'irrigation.

3.3.8. - Influence de la recharge sur la salinité et sur la qualité des eaux.-

Il est évident que si les sols de surface sont salins, soit naturellement, soit par suite d'irrigations prolongés, l'infiltration entraînera petit à petit ces sels qui finiront par atteindre la nappe.

C'est ce que montrent certaines régions de Californie ou d'autres zones plus ou moins arides. Le phénomène est à étudier sérieusement, la recharge pouvant dans ce cas éviter les sels de la surface si on utilise des puits ou des fouilles pour l'absorption. Si les prélèvements à faire dans la nappe rechargée doivent donner de l'eau potable, il est aussi nécessaire de s'occuper de l'aspect bactériologique du problème. Jansa estime que la distance de filtration de l'eau rechargée (entre le point de recharge et l'endroit du captage) doit être de l'ordre de 250 m, cette distance pouvant être réduite à 150 m s'il s'agit de sables fins. Certains essais effectués par l'auteur en Belgique lui donnent à penser que cette distance ne peut guère être réduite.

3.3.9. - Economie du procédé.-

On se rend compte que le prix de revient de l'emmagasinement sera toujours un cas d'espèce. Il est un "sous-produit" à prix de revient minimum dans le cas des nappes rechargées par l'irrigation ou par des eaux dont on ne peut se débarrasser que par infiltration. Mille circonstances exerceront leur influence sur ce prix de revient dans les conditions habituelles.(installations nécessaires, valeur des terrains, etc.) On a cité un prix de 5 $ par acre-foot (1200 m3 environ) pouvant tomber à 3 $ pour les installations à grand rendement (Loverty).

3.4 - Recharge - Barrière contre les intrusions d'eaux salines et surtout d'eau de mer. On sait que du fait de sa plus grande densité, l'eau de mer s'infiltre en coin sous les eaux douces dans les nappes des régions côtières. L'interface lorsque les nappes sont au repos, se situe sensiblement à une profondeur égale à 40 fois l'altitude de nappe d'eau douce au-dessus du niveau de la mer. Mais lorsque l'on pompe cette eau douce (l'eau des dunes par exemple), la dépression produite par le pompage relève le niveau de l'eau salée dans la direction des puits, la rendant impropre à l'usage si les pompages sont intensifs. On a imaginé de relever artificiellement la charge de l'eau douce par recharge entre la mer et les captages, chassant par le fait même l'eau salée et constituant une barrière contre son intrusion.

3.5. - Il en peut être question dans ces quelques pages d'épuiser le sujet, qui a d'ailleurs provoqué l'éclosion d'une littérature très vaste. Une très heureuse bibliographie annotée fait l'objet du Water Supply Paper 1477 du Geological Survey par le Prof. David Todd. C'est un travail avec des centaines de références, qu'on peut considérer comme complet pour tout ce qui a été publié jusque fin 1954. Pour la littérature plus récente on consultera particulièrement :

Mullnix L.A. - The interest of the Dept. of Water Ressources in artificial recharge - Proc.Conference on Ground Water Recharge 1959.

Richter R.C. - Geologic consideration on artificial recharge - Bull. Geol. Soc. Amer. 56, 1661 , 1955.

Schiff Léonard - The Darcy Law in the selection of water spreading systems for ground water replenishment. Publ. 41 - Assoc. Intern. Hydr. Scient. 1956.

Schiff Léonard- The use of filters to maintain high infiltrations rates in aquifers for ground water Recharge - Publ. 44 Assoc. Intern. Hydr. Scient.

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Point de l'ordre du jour : A. 3

Viet-Nam

LES RESSOURCES HYDRAULIQUES DU VIET-NAM

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de Saïgon

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Directeur de l'Ecole Supérieure d'Electricité de Saigon

1/- ORGANISATION DES SERVICES METEOROLOGIQUES ET HYDROLOGIQUES DU VIET-NAM.

a)- Service météorologique.

Jusqu'en 1961, il n'existait encore au Viêt-Nam aucun organisme central susceptible d'effectuer le relevé de toutes les caractéristiques nécessaires à l'évaluation des ressources hydrauliques. Les quelques données que nous possédons sont incomplètes car elles portent sur des périodes trop courtes et concernent des projets bien définis. Nous avons cependant grâce à la Direction de la Météorologie qui relève du Secrétariat d'Etat aux Travaux Publics et Communications, des données climatologiques assez intéressantes (température, humidité, pluie, évaporation, vent, etc...) qui, jointes à des renseignements topographiques et géologiques de certaines régions déjà prospectées permettent dès maintenant une évaluation sommaire de nos ressources en énergie hydraulique.

Depuis 1955, cette direction n'a cessé de se développer comme en témoigne le tableau 1 suivant :

" TABLEAU 1 "

	Stations Météorologiques	Stations climatologiques	Stations pluviométriques
Année 1955	13	3	32
Année 1962	23	23	265
Progression	77%	667%	728%

(Ces chiffres tiennent compte également de la remise en état d'un certain nombre de stations qui ont été détruites pendant la guerre).

Mais les moyens en hommes et en matériel dont elle dispose sont encore insuffisants.

Ainsi, certaines stations climatologiques sont exploitées par un personnel emprunté à d'autres services : écoles d'agriculture, fermes, plantations etc... Dans les stations pluviométriques, les observations sont faites seulement deux fois par jour par un agent volontaire local. Seules, les stations météorologiques importantes, avec un effectif de 6 agents, font des observations horaires. Membre depuis 1955 de plusieurs organisations météorologiques internationales, le Viêt-Nam participe régulièrement et activement à toutes les conférences et congrès intéressant ce domaine.

b)- Service hydrologique.

La remarque qui s'impose (les experts étrangers l'ont aussi plus d'une fois mentionné dans leurs rapports) c'est qu'il n'existe aucune documentation hydrologique valable concernant la plupart de nos cours d'eau. Seule la rivière du Danhim, dont les travaux d'aménagement hydroélectrique sont en cours, a été bien étudiée depuis 1925, avec une interruption de quelques années durant les conflits. Récemment, le projet du Mékong inférieur, patronné par les Nations Unies, a permis l'installation de plusieurs postes d'observations hydrologiques mais uniquement dans la région du delta, dont les résultats servent d'ores et déjà à l'étude sur modèle mathématique qui permettra de déterminer (d'une manière plus rapide et plus économique que le modèle réduit physique) l'influence que pourrait avoir l'ouvrage projeté du Tonle Sap sur la régularisation de la crue et la salure des eaux.

Ainsi, on ne saurait trop insister sur l'urgence et la nécessité de créer une direction hydrologique nationale ayant pour but l'établissement et l'exécution de tout un programme d'observations rationnel couvrant tout le territoire. Des stations de jaugeage clefs devront être installées sans plus tarder, des mesures de débits solides, des campagnes de sondage géologiques devront aussi être menées parallèlement.

En général, une bonne documentation hydrologique d'ensemble fait défaut dans les pays sous-développés qui ont malheureusement tendance à ne concentrer leurs efforts que dans des projets d'équipement bien limités. Etant donné que c'est l'année moyenne qui constitue une donnée essentielle en hydrologie, un manque d'informations s'étendant sur plusieurs années risque d'entraîner des erreurs fatales. Il nous paraît donc plus raisonnable de retarder une ou deux réalisations ou même de les sacrifier, le cas échéant, pour consacrer les crédits disponibles à une organisation systématique des services météorologiques et hydrologiques.

Ayant compris l'importance de la question, le Secrétariat d'Etat aux Affaires Rurales vient de créer à Saigon un service hydrologique dirigé par des ingénieurs et en provinces 6 annexes ayant à leur tête des agents techniques.

Ce nouveau service a, au démarrage, deux principaux objectifs :

- Rassemblement de toute la documentation existante en vue d'une analyse complète.
- Création d'un réseau de postes d'observations en vue de fournir les renseignements manquants.

2/- POTENTIEL HYDROELECTRIQUE BRUT DES EAUX DE SURFACE DU VIET-NAM.

Les ressources hydroélectriques du Viêt-Nam n'ont pas, avant la présente note, fait l'objet d'une étude d'ensemble. Malgré le caractère imprécis de certaines données, cette étude (tableau 2) qui constitue la première évaluation du potentiel brut des eaux de surface, fait apparaître sous un jour entièrement nouveau, le rôle que pourra et devra jouer dans les années à venir la houille blanche dans l'économie du pays.

La méthode employée est plus ou moins semblable à celle préconisée par le Comité de l'Energie Electrique de la Commission Economique pour l'Europe et également par le Sous-Comité de l'Energie Electrique de la Commission Economique pour l'Asie et l'Extrême-Orient. Dans la formule de base $W = \frac{VH}{367}$

W s'exprime en millions de kWh, V en millions de m^3
et H représente l'altitude en m au dessus du niveau de la mer.

Nous avons pu relever les valeurs moyennes suivantes :

"TABLEAU 2"

Bassin ou secteur de captage	Caractéristiques Topographiques		Caractéristiques hydrologiques					Degré de précision des statistiques (a)	Potentiel hydroélectrique	
	Superficie $S(10^3 km^2)$	Altitude moyenne au dessus du niveau de la mer H(m)	Pluie tombée P(mm)	Pluie écoulée P_e(mm)	Coefficient d'écoulement C (%)	Ecoulement spécifique annuel moyen (l/sec/km2)	Débit annuel moyen $Q(m^3/sec)$		Potentiel annuel brut des eaux de surface W (10^9 kWh)	Densité moyenne d (kWh/m^2)
Bassin I (Dong-Nai)	13,41	657	2545	1302	51	41,3	553	1	31,18	2,32
Bassin II (Ea-Krong)	12,85	593	2018	696	34	22,1	284	2	14,45	1,12
Bassin III (Song-Bai)	13,65	453	1900	477	25	15,1	206	1	8	0,58
Bassin IV (Krong-Poko)	12,72	912	2250	827	37	26,2	333	1	26,06	2,05
Bassin V (Tra-Khuc)	5,22	488	3089	1804	58	57,2	298	1	12,48	2,39
Bassin VI (Song Thu-Bon)	10,58	536	3200	1787	55	56,7	600	1	27,60	2,61
Bassin VII (Dai-Giang)	2,49	414	3300	1978	60	62,8	156	1	5,54	2,22
Bassin VIII (Han-Giang)	3,83	356	2528	1425	56	45,2	173	1	5,28	1,38
Bassin IX (Song-Be)	8,48	282	2511	1445	57	45,9	389	1	9,41	1,11
Bassin X	9,67	177	1787	283	16	8,9	86	1	1,30	0,13
Bassin XI	8,58	167	1620	120	7,4	3,8	33	1	0,47	0,05
Bassin XII	8,19	190	1840	340	18	10,8	88	1	1,44	0,18

(a) 1 = chiffre basé sur une période d'observations de 10 ans ou plus
2 = " " " " " " comprise entre 5 et 10 ans.

- Précipitation annuelle 2.000 mm
- Evaporation annuelle 1.100 mm
- Absorption due à la végétation 300 mm
- Coefficient d'écoulement 40 %

Théoriquement, avec un débit moyen, la puissance installée serait de 16,35 M.kW soit 1,25% par rapport à l'Asie (1.330 M.kW) ou 0,43% par rapport à l'ensemble du globe (3.800 M.kW). Si l'on prend une durée d'utilisation théorique de 8.760 h et un rendement de 100% la production atteindra 143 milliards de kWh.

La densité moyenne du potentiel brut calculée pour l'ensemble du territoire (0,8 kWh/m^2) est un peu supérieure à celle de l'ensemble de l'Europe Continentale.

Le tableau 3 suivant permet d'avoir une idée plus nette de la question :

" TABLEAU 3 "

Pays	Potentiel brut 10^9 kWh	Densité 10^3 kWh / ha
- Suisse	144	34,88
- Autriche	152,5	18,19
- Yougoslavie	205,9	8,06
- Viêt-Nam	143,2	8,06
- Turquie	536,6	6,98
- France	255,0	4,63
- Tchécoslovaquie	39,3	3,07

Le potentiel hydroélectrique exploitable a été évalué à environ 7,5 milliards de kWh seulement, se répartissant comme suit :

Bassin du Dong-Nai	6.10^9 kWh
Bassin du Song Thu Bon	1.10^9 "
Bassin du Dai-Giang	$0,510^9$ "

Normalement le pourcentage du potentiel hydroélectrique exploitable sur le potentiel brut (5,25%) devra augmenter considérablement dans le futur pour s'approcher du maximum théorique en raison à la fois des progrès techniques et des conditions économiques favorables. Le seul facteur qui pourra jouer, dans le sens inverse, réside dans les difficultés d'exploration des sites valables à cause de l'insécurité qui y règne.

A l'heure actuelle, la production hydroélectrique du Viêt-Nam est négligeable : 2% de la production totale (à base thermique) qui est de l'ordre de 300 millions de kWh.

Cette situation anti-économique sera renversée, dans les années à venir avec la fin des travaux du DANHIM (160.000 kW - 800 millions de kWh) et la réalisation d'autres projets en cours d'études tels que : Tri-An et Sông Thu-Bôn.

3/- RECOMMANDATIONS GENERALES.

Beaucoup de temps et d'argent ont déjà été consacrés à l'étude de l'eau au Viêt-Nam. Mais cette étude visait essentiellement à l'amélioration des récoltes par l'irrigation et le contrôle de la salinité.

Des gaspillages inévitables se sont produits : certains barrages en terre construits manuellement sans technique appropriée n'ont duré fatalement que le temps séparant l'étiage d'une crue annuelle. La bonne volonté des paysans, pour intéressante qu'elle soit, ne peut malheureusement résoudre tous les problèmes techniques qui sont de plus en plus le travail de spécialistes.

A notre avis, pour que le pays puisse réaliser de nouveaux progrès dans le domaine qui nous intéresse, il convient de nous fixer comme principaux objectifs :

a)- Météorologie :

- En première phase, tendre à une répartition minimum de 1 pluviomètre par 1.000 km2 sur les parties hautes des bassins versants (dans les plaines cette densité est souvent dépassée).

- En seconde phase, obtenir une densité de l'ordre de 1 pluviomètre pour 200 à 300 km2 dans les zônes les plus intéressantes.

- Installer 1 pluviomètre enregistreur pour 10 pluviomètres non enregistreurs et des pluviomètres totalisateurs sur les parties hautes ou peu accessibles des bassins (visite tous les 6 mois).

- Etablir des stations agrométéorologiques.

b)- Hydrologie :

- Installer systématiquement sur tout cours d'eau important (bassin versant de 2.000 à 3.000 km2 au moins) des échelles limnimétriques au moindre prix.

- Faire une campagne de mesures de débits. Dans la première année, on s'efforcera de faire à chaque station limnimétrique 2 ou 3 mesures de basses eaux, 2 ou 3 de moyennes eaux et au moins 1 de hautes eaux afin d'avoir aussitôt que possible un tarage provisoire.

- Procéder à une reconnaissance générale des affluents des régions à développer :

i)- étude sur cartes ou photos aériennes,
ii)- délimitation des bassins versants,
iii)- reconnaissance sur le terrain,
iv)- reconnaissance pédologique des zônes irrigables,
v)- étude hydraulique,
vi)- évaluation préliminaire des aménagements.

Ce dernier travail doit être pris en charge dès maintenant par la Direction Générale de l'Electricité du Viêt-Nam.

c)- Formation professionnelle :

- équiper sans plus tarder un laboratoire d'essais, de contrôle et de recherches hydrauliques.

- créer dans l'enceinte du Centre National Technique de Phu-Tho une école pilote (genre Gurcy le Châtel de l'Electricité de France) formant des techniciens hydrauliciens dont la spécialisation se fera en fonction des besoins prévisibles.

Il serait souhaitable que des experts aussi qualifiés que ceux du projet du Mékong puissent apporter à cette oeuvre leur collaboration active en donnant des cours ou conférences, qui seront d'autant plus profitables aux étudiants que les sujets traités se rapporteront davantage aux problèmes locaux.

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FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.3.1.1

Nigeria

THE DEVELOPMENT OF WATER SUPPLIES IN EASTERN NIGERIA

By D.H.S. SOUZA-OKPOFABRI,
Dipl. Eng. D.I.C., A.M.I.C.E., A.M.I.W.E.

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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THE DEVELOPMENT OF WATER SUPPLIES IN EASTERN NIGERIA

BY

D.H.S. SOUZA-OKPOFABRI, DIP. ENG.,
D.I.C., A.M.I.C.E., A.M.I.W.E.

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INTRODUCTION

1. The natural desire of the people for improved standard of living and Government's determination to diversify the economy by industrialisation and modern agricultural methods have created a most pressing need for providing potable water for domestic and industrial use in the urban as well as the rural areas. It is to meet this demand that the Eastern Nigeria Government has earmarked £6½ million in its current development programme (1962-68) for water supply to urban and rural inhabitants.

Although the limitation imposed by lack of adequate funds and data make the planning, design and construction of water supply installations rather difficult, the improvement in the health and the standard of living of the people served by the relatively small number of schemes so far completed, indicate that Government's decision is a step in the right direction.

2. Generally, water supply in Eastern Nigeria is classified into the following two main categories, all of which are maintained and operated on behalf of the community by the Ministry of Works.

(a) Urban Water Supplies. - Consisting of installations serving populations of between 10,000 and 150,000 people confined within a radius of 5 miles from the centre of population and providing water to meet domestic and industrial demands. So far, there are 14 such installations.

(b) Rural Water Supplies:

(i) Pumped and piped schemes which, as the name implies, provide pipe-borne water for rural communities with population of between 5,000 and 35,000 scattered over a very much wider area than is the case with (a) above. As it is to be expected, the cost of distribution main in such schemes (there are now 33 such schemes in construction or completed) is more than 60% of total cost of the schemes.

(ii) Waterpoints which consist of wells, spring improvements and shallow boreholes are designed to supply small communities. One such point is provided for 500 persons. There are presently 1,304 water points.

3. In addition to the above, there are institutional schemes which are essentially pumped and piped schemes constructed by Government to serve medical and educational institutions but which are operated and maintained by the institutions concerned.

GENERAL DESCRIPTION
TOPOGRAPHY, HYDROGEOLOGY, CLIMATE AND POPULATION.

4. Eastern Nigeria is one of the four constituent units forming the Federation and is self-autonomous in all matters except Foreign Affairs, Police and Communications which are the responsibilities of the Federal Government. Its erstwhile five provinces are now divided into twelve provinces varying in size between 806 square miles in the Annang Province and 3,699 square miles in Enugu Province, the total area covered by the region being 29,500 square miles(1).

5. It is of fairly uniform relief, the only highlands of note being Oban Hill in Calabar Province which rises to 3,770 feet above sea level and forms the hydrological centre of the region, the Enugu escarpment which is 1,715 feet above sea level and the Awgu-Okigwi-Bende group, which rises to 1,287 feet above sea level and forms the watershed for rivers which flow westerly into the Niger system or easterly as tributaries of the Cross River.

6. Apart from the Niger and Cross River systems into which a number of seasonal and perennial streams flow, the Imo and Kwa Ibo rivers flow into the Bight of Biafra at Opobo and Eket respectively.

7. All the four major rivers are subject to seasonal fluctuations of between 12 and 30 feet, a phenomenon which presents considerable problem in the design of intakes from these rivers or their tributaries. Along the last 140 miles of its flow and before discharging into the Bight of Biafra, the Niger develops into one of the most well-known deltaic formations in Africa, being 100 miles wide at its broadest point. Over 60% of the area covered by the delta is in Eastern Nigeria and although the area abounds in rivers and streams, it is one of the most difficult from the point of view of water supply, owing to the lack of easy access into it.

8. The region has two seasons:-

a., rainy season, which extends from March to October in the south and from April to September in the north, the mean annual rainfall being of the order of 120" in the south and 60" in the north; and

b., the dry season.

Temperature is fairly constant all the year round at 85°F and the relative humidity varies between 90% and 98% in the north and south respectively. Normally a figure of 22% and 55% of the total annual precipitation is allowed for run-off and evapo-transpiration respectively in the design of water supply schemes. So far, supply from impounded reservoir has been restricted to a small, experimental village scheme in the very difficult Cross River plain area and works of similar nature will depend on the result of observations now being made.

9. The principal geological division of Eastern Nigeria, is as shown in fig.1. From the point of view of water supply, each area except the

central (coastal sand) plain presents serious difficulties. Whilst groundwater condition in the Bende-Ameki and Imo shales group are unpredictable, groundwater in some parts of the delta area is susceptible to high salt content and cannot be used for domestic purpose without treatment. Also the Cross River plain, owing to the impermeability of the soil, has no suitable groundwater reserve within reasonable depth of the surface. Generally, geological data and information on groundwater movement are very sparse and a great deal of investigation and tests need to be carried out yet.

10. With regard to quality, groundwater is usually preferred as it can be put into reticulation with minimum treatment, aeration and pH correction. Surface water is usually soft and of good chemical quality, but is in most parts, heavily charged with pathogens and therefore need to be given full treatment - coagulation and/or sedimentation, filtration, pH correction and sterilisation before use.

11. Up to date, there had been three population censi taken, the result of the latest (1962) is now awaited. In the 1953 census, the population of Eastern Nigeria was recorded as 7,249,692, of which at least, 6 million were purported to be living in the rural areas(2). There are indications that a sizable increase has been recorded in the 1962 census. In view of the publicity and the preparatory work conducted prior to the census, this is not surprising.

12. In the design of water schemes, population increase of 1½% p.a. compound increase is adopted for rural schemes whilst a figure of between 8% and 3%, depending on nature of development, is used for urban schemes.

GENERAL POLICY

13. As indicated above, where groundwater is available in sufficient quantity and within reasonable depth, it is preferred to surface sources hence, a large number of pumped and piped schemes for rural areas depend on well and borehole sources. Five of the urban schemes are supplied from surface or a combination of underground and surface sources. In all but one of the installations where surface sources are used, provision is made for full treatment of the water.

14. Effort is now being made to standardise on pumping equipment with a view to facilitating training of operators and reducing the stock of spares held. Generally, 100% standby is provided for pumping equipment.

15. Except in very few cases where pressures are higher than those allowable for this type of pipes, asbestos cement pipes are used for both rising and distribution mains because of their low cost, speed and relative ease of construction. Until recently service connections were made with galvanised iron pipes but the use of polythene pipes for normal work and of copper for internal plumbing for high class buildings have been introduced.

16. Storage capacity of a minimum of one full-day's demand in 30 years for ground level reservoirs and a ½-day's demand for water towers is allowed in the design of new and improvement to existing schemes.

17. As of present, chemical analysis of all water is carried out by the Ministry of Commerce and bacteriological analysis by the Ministry of Health. It is proposed in due course to provide laboratory facilities in the Ministry of Works as it is thought that apart from providing a means of effective quality control, it is essential to relate the design

of schemes to the result of tests carried out on the raw water and this is only possible if the tests are carried out under the direct supervision of the engineers responsible for design.

CONCLUSION

18. I have indicated in chap.14 that the main reason for standardisation of equipment is to facilitate the training of operators. In a country where there is an abject lack of the simple practical knowledge of mechanical equipment amongst potential trainees, and quick servicing facilities are not available, the need for the training of operators cannot be over-stressed. This need is even more pressing in the water industry, for which there is, as yet, no organised training schemes. At the moment, the ratio of water supply employees to number of people receiving a piped water supply is less than 0.05 per 10,000 and this is by no means, due to the use of very efficient and labour saving plant and equipment.

19. There is no shortage of potential trainees and the present situation has only arisen from the fact that facilities for training were not available in the past. The development programme makes it incumbent on the Government to turn out waterworks staff much more quickly than would be expected in the more developed countries and it is the author's opinion that this demand can only be met by offering the necessary training in the course of the execution of their normal duties. In effect, the trainees should be taken on as apprentices with facilities provided for the continuation of their general and technical education at evening classes or part-time day classes. The advantage of such an arrangement is that the trainee will acquire experience and skill at the same time as he improves his education.

20. In order to ensure that trainees obtain the full benefit of such a scheme and to reduce the period of training to a minimum, it will be necessary to specify a basic educational qualification of Middle I V Secondary with a fair knowledge of mathematics, elementary physics and chemistry. The views of other participants on this subject will be very much appreciated.

21. Whereas it is agreed that urban water supply scheme should be financially self-sustaining, it is the author's view that for some time yet to come, rural water supply will need to be treated as a most essential social service for which Government should continue to provide subsidies. It is possible that some pumped and piped schemes will eventually develop into urban schemes but until that stage is reached, the improvement in the health of rural people resulting from provision of piped supply will justify Government contribution towards the capital and running cost of all rural schemes.

ACKNOWLEDGMENT

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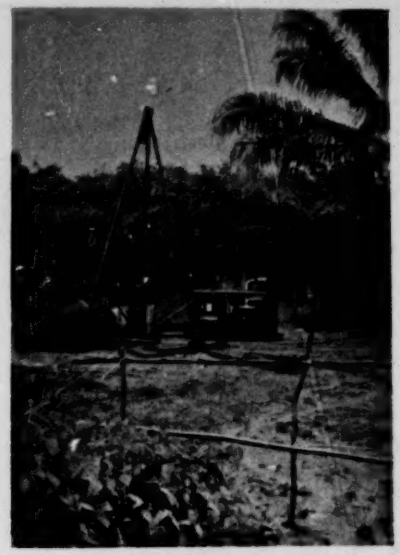


Fig. 1 Drilling for borehole
Nsukka

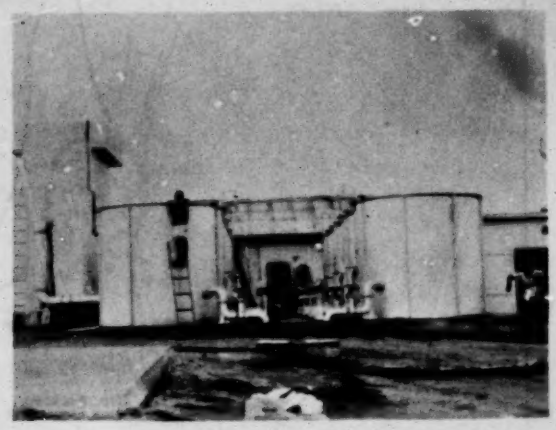


Fig. 2 High level pumphouse
Onitsha

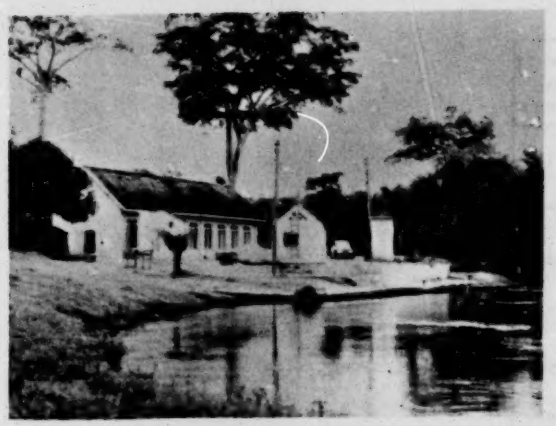
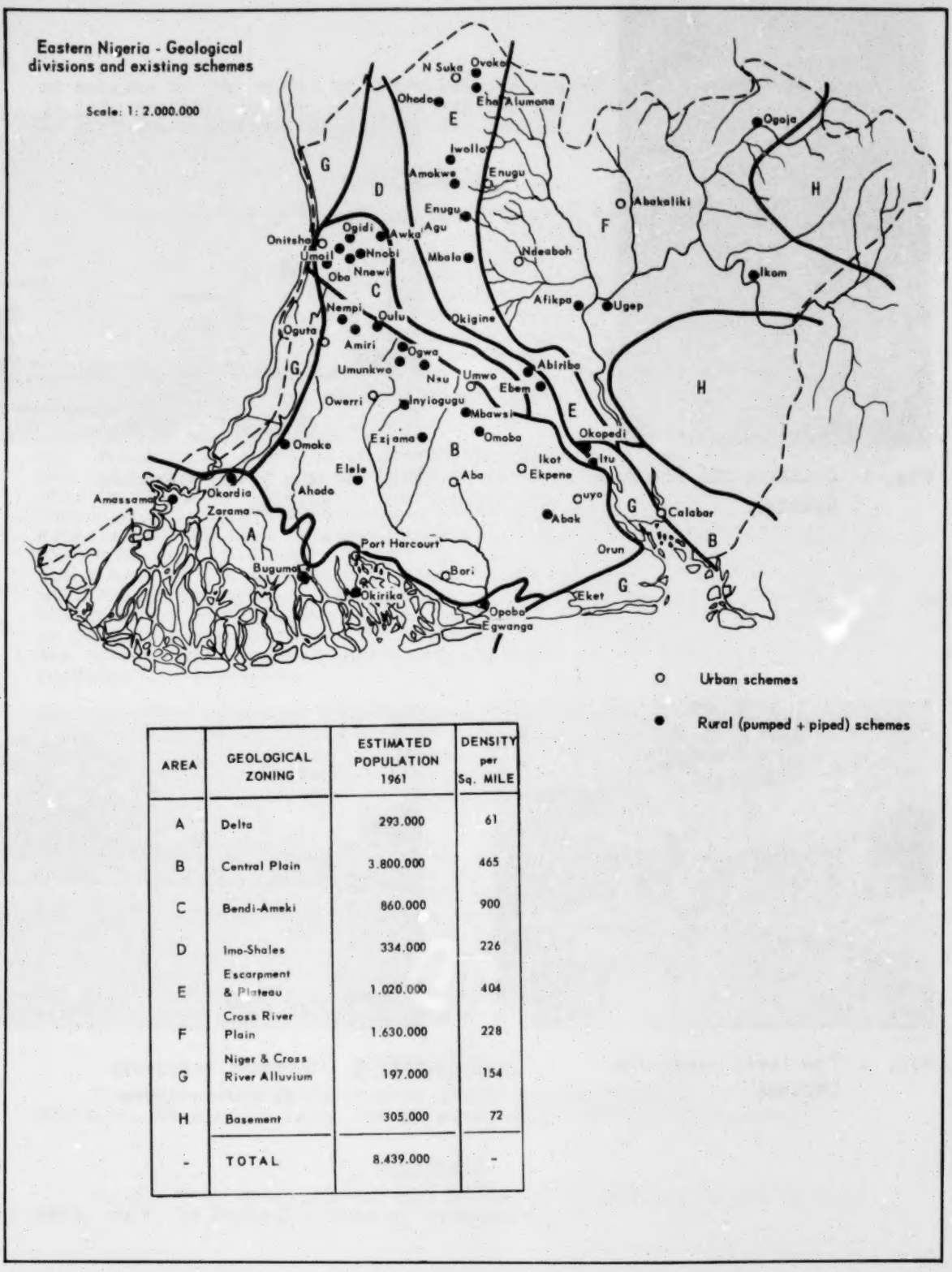


Fig. 3 Low level pumphouse
Onitsha

Fig. 4 Impounded reservoir
Abina rural scheme



AREA	GEOLOGICAL ZONING	ESTIMATED POPULATION 1961	DENSITY per Sq. MILE
A	Delta	293.000	61
B	Central Plain	3.800.000	465
C	Bendi-Ameki	860.000	900
D	Imo-Shales	334.000	226
E	Escarpment & Plateau	1.020.000	404
F	Cross River Plain	1.630.000	228
G	Niger & Cross River Alluvium	197.000	154
H	Basement	305.000	72
-	TOTAL	8.439.000	-

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Agenda Item : A.2

Ceylon

INTEGRATED RIVER BASIN DEVELOPMENT IN LESS DEVELOPED AREAS IN CEYLON

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INTEGRATED RIVER BASIN DEVELOPMENT IN LESS DEVELOPED AREAS IN CEYLON.

by

V. N. RAJARATNAM.

(Assistant Director, Irrigation Department, Ceylon)

1. Development of less developed areas in Ceylon.

(a) Wet and dry zones of the Island.

The country divides itself into two distinct zones called the wet and dry zones according to rainfall. The zone has two rainy seasons with an average annual rainfall of 110 inches spread over the two seasons. The dry zone has one rainy season with an average annual rainfall of 60 inches of which 80% is concentrated in the three months of the rainy season. The wet zone covers the South Western sector of the island and the dry zone comprises the rest.

The pattern of agricultural development of the island has been influenced by the weather conditions in the two zones. Thus the wet zone with its abundant moisture and steady temperatures, has been fully developed under economic crops such as tea, rubber, coconuts, and rice which is the main subsistence crop. The present economy of the island therefore is dependent almost entirely on the wet zone which is only a third of the area of the dry zone, and having the largest concentration of population. The dry zone, although it has one rainy season, subsistence crop such as rice, cannot be cultivated successfully without irrigation. Without water the land in the dry zone has no value but the rainfall here is such that with storage best use of the water can be made. The development of this area therefore lies in the effective planning of its land and water resources.

(b) General characteristics of the dry zone.

Dry zone area in ancient times supported a large population and the main activity had been the production of rice and other subsistance crops. The art of irrigation was practised in this country for more than twenty centuries and there still remain to this day some of the reservoirs and diversion structures which the ancient people had constructed. But now the dry zone is an unpeopled land as jungle covers the greater part of it. In many parts of the dry zone the population is below 50 person to the Sq.Mile. The

people are found in small settlements in isolated villages near rivers and tanks (artificial reservoirs) where they earn a meagre livelihood on the fringes of the jungle.

(c) Present stage of Development of the dry zone.

It has been stated earlier that this region has only one rainy season, and cultivation of subsistence crops is attendant with hazards on account of the vagaries of the monsoon. Most of the unused lands lie in this region but the lands can only be developed by irrigation.

The governmental activity since the turn of the century was exclusively directed to restoring, maintaining and operating the ancient irrigation schemes. Then a slump in 1931 in the principal commodities of the country, tea, rubber and coconut reduced employment in the parts of the wet zone where those industries are situated and brought about the vital necessity for expansion to the dry zone as a means of livelihood to the people.

The population pressure in the wet zone forced the government to initiate a scheme of Colonisation and land utilisation in the dry zone. The general policy of the Government had been to establish the peasant on a unit of holding consisting of a wet - land area and a high-land area to enable him to settle on the land and derive from it an income sufficient to maintain himself and his family in reasonable circumstances. He is to obtain the money income from the wet land by rice cultivation while his homestead is to be on the high-land at a reasonable distance from the wet land where besides his home he can cultivate it with permanent crops and vegetable mainly to meet his own requirements of food.

In the earlier schemes, the wet land unit was 5 acres and the high-land 3 acres. These units were based on the agricultural produce prevailing in 1935. As the price of agricultural produce improved, the demand for land by the peasant settlers increased and it was then decided to reduce to 3 acres of wet-land and 2 acres of high-land. The new projects are being planned and constructed on this basis.

Due to colonisation projects, development under irrigation in the areas where the projects were situated showed better progress. The lands developed in the dry zone under irrigation is now approximately 0.35 million acres.

(d) Pattern of future development in the dry zone.

1. Need for further development.

Ceylon is essentially an agricultural country but she spends annually a large amount of money in importing basic food and other commodities which is a large drain on the national income. By producing these commodities locally, the savings effected in expenditure could be utilised in developing other requirements which are necessary for national security and well being. There is thus a great

need for the development of land and water resources so as to make the country self-sufficient in those articles of food and essential goods which could be produced in the country economically.

Dry zone needs water for the cultivation of rice which is the staple food of the people. For any programme aiming at the increase of rice production an assured supply of irrigation water is a prime necessity. Many of the existing minor irrigation schemes do not meet this requirement as they depend on uncertain natural stream flow during the rainy season. The rainfall varies greatly from one part of the country to another, from one season of the year to another, as well as from one year to the next. Thus if the rains are late, the whole cultivation programme receives a set back as tanks are not replenished in time to commence cultivation and in the dry zone owing to shortage of water only one crop of rice a year could be grown.

Water is also required for developing hydro-electric power as the country has no known fuel resources for producing thermal power. It is also required for domestic and industrial use as very little underground water is available. Floods in the larger rivers cause considerable damage during heavy rains necessitating expensive protective measures to valuable property and cultivation.

ii. Development through multi-purpose projects.

The question therefore arises as to what would be the best solution to the present problems. The answer to this is an integrated river basin development. Water has to be stored in a large scale and its utilisation so planned not only for irrigation and flood control but also for power development, industrial and domestic supply, fish culture, preservation of wild-life, recreation etc. Thus all development should be planned as integral parts of a comprehensive plan for the development of a basin or region. What is clearly needed is a system in which each separate element fulfils its own special function complementary to the functions of the other elements.

The works undertaken in the past were mainly single purpose schemes designed to meet the immediate requirements. Therefore, development of water resources had been fragmentary approaches to the main problem and its associated problems of flood control, irrigation, land development, hydro-electric power generation, soil conservation and forestry. But when the engineering effectiveness and economic justification of these schemes are considered from the point of view of an overall development pattern the multipurpose concept provides the answer.

2. Planning of Integrated river basin developments.

(a) Manageable unit for planning.

River developments must envisage the development of an area in terms of all its needs and all its resources and are intended to bring about an integrated development. In order therefore to prepare an overall pattern for the development of water resources the most convenient manageable unit appears to be the river basin or in some cases a group of basins. Though a basin may form a unit for planning yet it need not be in complete detail. It can be a framework into which can be fitted in proper sequence all other activities, projects and plans as they get developed stage by stage.

(b) Division of the island into natural river basins.

The first operation in the process of planning has been to divide the entire island with its total surface area of 25,300 sq. miles or about 16,200,000 acres into its various 103 component natural river basins. In addition to these, there are about 94 small coastal tracts, the water potential of which is negligible. Of these 103 river basins, those which have each a drainage area of 100 sq.miles and over have been classed as Major River Basins. There are in all 39 in number and they range from an area of 100 sq.miles each to a little over 4,000 sq.miles, covering an aggregate drainage area of about 20,600 sq.miles which represents 80% of the entire surface area of the country. Grouping of various river basins of the Island into convenient zones or regions indicate that better results could be achieved in the development of the water and land resources. Thus one or more contigouous river basins together with a few adjacent minor river basins are considered as a zone or region, where the water resources of all the component basins are first pooled together and then allocated among the individual basins.

(c) Rivers in Wet and Dry Zones.

The total discharge of all rivers is estimated at 32,722,000 Ac.ft. The catchment areas of the wet zone drain 18,987,000 ac.ft. say 58% of the total run-off on the island with a ratio of run-off to rainfall of 56%. The catchment areas of the dry zone some of them partially located in the wet zone, drain 13,735,000 ac.ft. with ratio of run off to rainfall of 20%. There are 330,000 acres of lands which receive irrigation at present in the dry zone. It is estimated that a further 3.5 million acres of land are available for future development.

Of the 39 major river basins 29 are located in the dry zone and 10 in the wet zone. By far the largest river basin in the island is that of Mahaweli Ganga, covering a drainage area of 4,034 sq.miles of which an extent of 820 miles lies in the wet zone and the balance of 3,214 sq.miles in the dry zone. The problem in the wet zone is more of drainage, that is quick exit of the surplus water to the sea, and prevention of floods than of irrigation, due to the fact that wet zone rivers are perennial. In the dry zone on the other hand, the problem is two-fold namely (a) conservation of the water resources and (b) drainage and prevention of floods. Since the wet zone is fairly well developed agriculturally, the future development from the point of view of irrigated agriculture has to be in the dry zone which with

its total drainage area of 19,000 sq.miles comprises 86 river basins. For the most effective planning it has been found necessary to group these 86 basins into 20 zones or regions.

3. Possible consequences of Projects on other potential users.

(a) Within-Basin Projects.

The Pattern of development for dry zone river basins envisages the utilisation of the entire water resources of the basin for the maximum development of that basin. Projects formulated will be within-basin Projects designed to bring out in general the ultimate potentialities for future development.

An assessment of the available water resources is first made and after allocating the resources to existing developments within the basin, quantity available for potential development is ascertained. The potential development envisaged in the dry zone area is mainly irrigation under rice and therefore land required for such development is also easily obtained. It has been found that lands in the dry zone are generally suitable for rice cultivation but land use surveys are later made to select the best lands which would give maximum income from the proposed cultivations. The within-basin projects are therefore developed so as to serve the needs of the existing developments as well as those of the potential users who will be brought into the areas mainly for irrigated agriculture as envisaged in the development plans of the basin.

Water before being issued for cultivation will be passed through hydro-power plants for the generation of electricity, if economically feasible. This has been found to be so in some of the projects investigated. However maximum development of hydro-electric power based on the resources available cannot be achieved in the dry zone as water required for irrigation has prbrity over power generation in the dry zone areas.

(b) Trans - basin diversions.

Studies made in some basins may indicate the need and desirability for importing water for use within a basin from an adjoining natural drainage basin. This would result in a corresponding reduction of within - basin uses. There is already a proposal to export water from the upper catchment of the Mahaweli Ganga which lies in the wet zone, to an adjoining basin for supplemental irrigation to 97,000 acres of existing cultivations to enable those lands to produce two crops a year instead of the one crop which obtains at present, and supply to 118,000 Acres of new lands. This is being done as an urgent measure to increase rice production.

(c) Ground water resources.

Greater part of the dry zone with the exception of the North-West Coastal belt, is composed of a complex of ancient crystalline rocks which have no capacity to hold or transmit water except where they are decomposed or disentegrated to appreciable depths. Lack of sufficient ground water has caused greater hardships to the settlers in the areas in obtaining water for domestic purposes in the dry

monsoon. It is felt that construction of reservoirs and the irrigation distribution net work in these dry zone areas will hel, replenish under-ground water supply which will be of great benefit to the people who will eventually settle in these regions.

4. Advantages and limitations of Multi-purpose Projects.

Maximum benefits are obtained from the development of a basin through multi-purpose projects as one project contributes to the other what it lacks. All projects are considered integrate units of a basin plan, and as such their economic feasibility is comprehended by the finding of feasibility for the over-all basin plan.

The primary benefit of developing water and land resources in the dry zone is the value of the rice produced by the peasant. Besides this the country gains by saving its external assets which are now used in obtaining it by imports from outside. Thus some benefits are tangible and are subject to measurement in monetary terms while others are less tangible and are not subject to accurate evaluation. A stable agriculture and availability of low cost power, together, provide a sound basis for industrial and commercial expansion and are therefore important to the region in particular and the country in general. These are not readily susceptible of monetary evaluation, but such intangible values have a far reaching effect on the social and economic structure of the country far more than the direct benefits derived from the project.

In order therefore to decide on the feasibility of a project, the benefit-cost ratio alone will not give the true picture when the purpose of the scheme is to develop the resources for the general welfare of the nation. It should not therefore have the same limitations of a private investment. Economic aspects have to be carefully considered in great detail to arrive at the feasibility of a project. Facts that come into consideration are property values, better paying jobs, lower cost of consumer goods, greater opportunity for employment, increase in external assets and greater national security. These no doubt benefits the private individual but in a less developed country it must be realised that on the prosperity of the private individual depends the prosperity of the nation.

5. Walawe Ganga Basin Development.

(a) Walawe Region - General description.

Walawe Ganga Basin has a total drainage area of 954 sq.miles and is located in the south central section of the island. It has a maximum length of about 50 miles and width about 30 miles. Smaller adjoining basins in the lower regions of the Walawe Ganga catchment have been included in the development for more effective planning. The total drainage area is therefore 1183 sq.miles, and the Walawe basin together with the smaller basins will be referred to hereafter as Walawe Region.

The northern portion of the Walawe region covering about one third of the total region area is located in the mountainous territory of what is called the wet zone which comprises the south west sector of the island and has two rainy seasons namely the S.W. and N.E.Monsoons

(April to September and October to March respectively). The rest of the Walawe region is located in the much flatter terrain at much lower elevation, of what is called the dry zone which comprises the balance three quarters of the island and has generally speaking only one rainy season, namely the N.E.Monsoon. The elevation of the upper reaches of the Walawe region ranges from 7,000 feet to 500 feet above M.S.L. The lower region is at an elevation ranging from 300 feet to 100 feet M.S.L.

(b) Walawe Ganga (Walawe river).

The Walawe river is one of the five largest perennial rivers of Ceylon, which has its source at an elevation of about 6,100 feet above M.S.L. in the mountain range known as the Adams Peak range, in the South Central Sector of the island. The river is 85 miles in length and drains a total area of 954 sq. miles and discharges annually a million Ac.ft. of water into the sea. At present all this water goes to waste without being exploited.

(c) Present development of Walawe Region.

i. Present land use.

The present development of the Walawe region is mainly tea plantations, rice fields, coconut and rubber plantations, teak plantations and towns, villages and gardens and covers an extent of 89,000 Acres which is about 14% of the total basin area. The rest of the basin is in jungle of which only small extents, in different parts of the basin have been cultivated with chena crops. Tea lands are located in the mountainous upper areas of the region and rice fields are situated in the flat terrain of the lower basin. Rice is also grown to a limited extent at the foot of the hills in the upper basin, along the banks of the upper reaches of the main Walawe Ganga and also along the banks of the Weli Oya and minor tributaries namely Katupal Oya, Rakwana Ganga and Andalu Ganga. Coconut plantations are more or less concentrated in the valley of the Timbolketiya Ganga and its two tributaries Rakwana Ganga and Andalu Ganga.

ii. Rice Cultivation.

The largest extent of 12,700 acres of existing rice lands in the region is situated in the coastal belt extending on both banks of the Walawe Ganga. These lands are irrigated by the existing Liyangahatota diversion weir constructed some years ago, across the main Walawe River at a site in the lower basin about 13 river miles from the sea. Two main irrigation canals one on each bank of the Walawe Ganga take off from this weir. The right bank canal commands 7,000 acres by direct irrigation while the left bank canal feeds a reservoir called the Ridiyagama Tank which irrigates 5,700 acres of rice lands. There is another diversion scheme called the Uggal-Kaltota Anicut Scheme constructed across Walawe Ganga at the foot hills of the upper basin. This Scheme irrigates 700 acres of rice lands by a right bank canal. Besides these two irrigation projects, there are some minor developments for the cultivation of rice exist in the Walawe Ganga Valley mostly in the upper region. These rice lands are either irrigated by several village tanks or rain fed, and total an extent of 9,000 acres.

iii. Population.

The population of the Walawe Ganga region is of the order of 250,000 which works out to about 260 persons per square mile of the basin. The population; however, as in any other river basin is & not uniformly distributed over the entire region but is concentrated in the areas of present development.

iv. Rainfall.

The mean annual rainfall over the region ranges from 145 inches to 92 inches in the mountainecus areas of the upper basin and 61 inches to 44 inches in the lower valley. For the region as a whole the mean annual rainfall is 82 inches. The region is one of the particular group of dry zone basins, in which on account of the mountainecus territories of the upper regions and their close proximity to the wet zone of the island, the S.W.Monsoon run off (i.e. April to September) is a fair proportion of the total run-off. Thus the rainfall and surface run off are more evenly distributed over the 12 months of the year than in the other basins of the dry zone.

v. Floods.

The maximum flood peak flow 150,000 cusecs and flood volume 670,000 Ac.ft. was recorded at Ambalantota (river mouth) in the Walawe basin in May 1940. The next biggest flood that has occurred in the past is that of August 1947. Floods of much lesser magnitudes have been experienced in other years.

(d) General Pattern of Future Development.

The studies of water resources, land use and geology undertaken have revealed that the general pattern of development of this region has to be mainly on agriculture. While the agricultural development in the hilly portion of the region has to be limited to the intensification of land use and application of conservation measures, the low land plain has been found to be suitable for development of irrigated cultivation over a large part of it. The terrain and drainage pattern of the area are of such a nature as to permit gravitational system of irrigation. The flow of the Walawe could also be harnessed to generate a significant amount of hydro-electric power. There are no mineral deposits in basin which merit development.

In order to obtain the best possible development for both power and irrigation, a system of dams and reservoirs are required as no single dam or reservoir could supply the irrigation and power requirements of a major development. According to the plan envisaged for the region it is proposed to bring under irrigation 107,000 acres for rice cultivation and develop 129 megawatts of installed power. The Project features include the construction of six reservoirs (total capacity 504,000 Ac.ft.) and necessary distribution and drainage systems for the lands commanded by the reservoirs. The possibilities of carrying out the development outlined in the plan envisaged are quite promising. Further investigations and studies have to be carried out to ascertain the physical and economic feasibility of the complete project and its component parts and such studies and investigations have been taken in hand for some of the reservoir projects. Detail investigations and designs were completed in respect of Chandrikawewa

reservoir scheme and this is now under construction. Designs have been prepared for Udawalawe Reservoir Headworks. Preliminary plans have been developed for headworks of Samanalawewa - Katupal Oya Reservoir Systems and it is proposed to bring in landless peasant colonists into this basin in accordance with the policy of the Government to work the lands which will be developed under the Project. Power produced will be very much more than the needs of the area at the present time and the surplus power will be supplied into the main power distribution net work.

(e) Benefits that will accrue from the Project.

The development of the region as envisaged will increase the production of food chiefly rice, and this will go a long way in effecting a saving in external assets a greater portion of which is now used in importing rice and other essential articles of food. The land required for development is Government land and no expenditure is involved in acquisition for project purposes. The availability of low cost power would stimulate industry and would create new opportunities for employment. Constructional activities of the various projects would reduce unemployment in the country and opening up of roads to project sites would make accessible existing village settlements. The construction of many reservoirs would also make a substantial contribution to flood control in the region.

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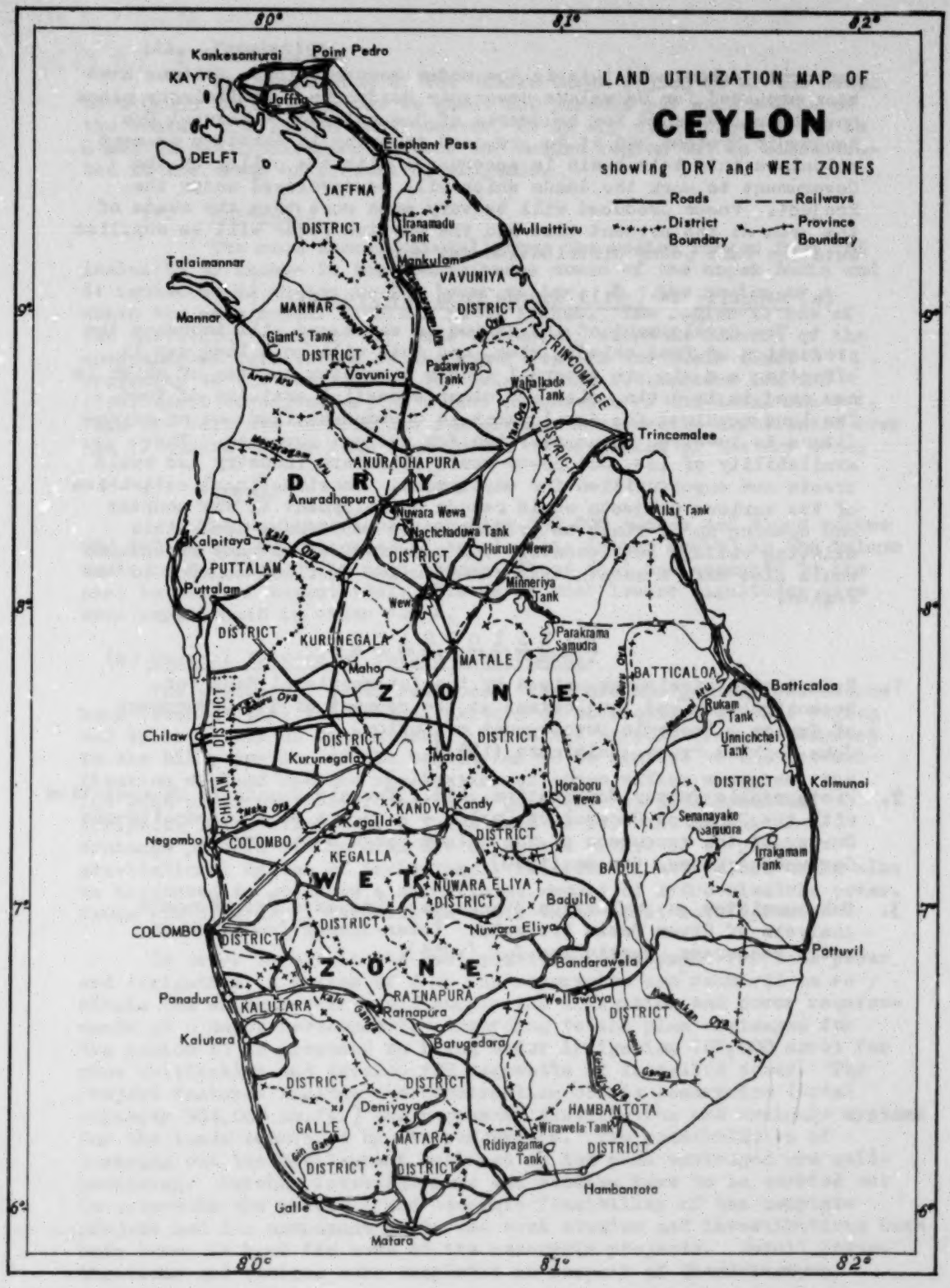
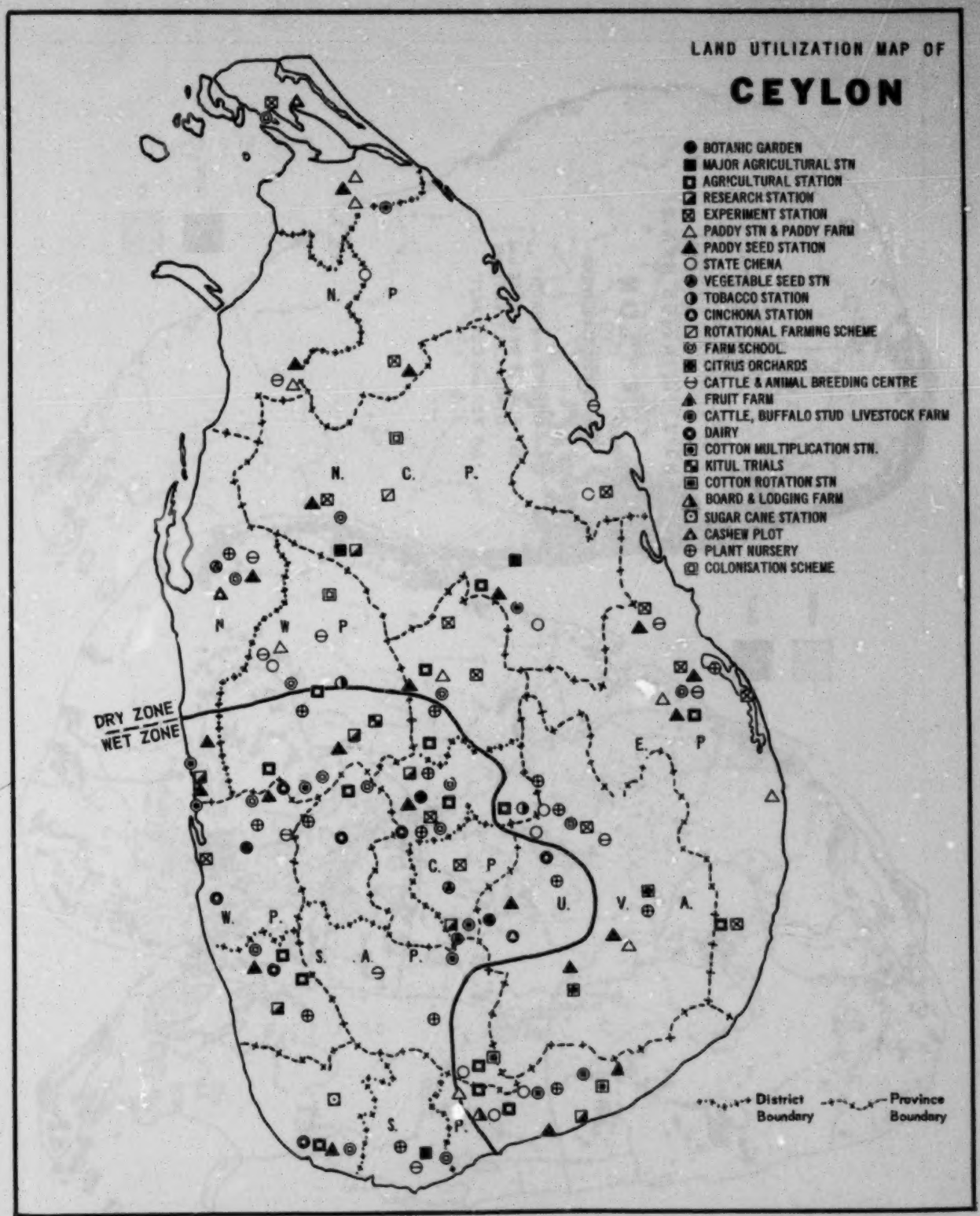

LAND UTILIZATION MAP OF
CEYLON
showing DRY and WET ZONES
Roads
Railways
District Boundary
Province Boundary
80°
81°
82°
9°
8°
7°
6°
Kankesanturai
Point Pedro
KAYTS
Jaffna
DELFT
Elephant Pass
JAFFNA DISTRICT
Iranamadu Tank
Mullaittivu
Talaimannar
Mankulam
VAVUNIYA DISTRICT
MANNAR DISTRICT
Mannar
Giant's Tank
Vavuniya
Padawiya Tank
Nuwara Aru
Yan Oya
TRINCOMALEE DISTRICT
Trincomalee
Wahalkada Tank
Mahaweli Ganga
ANURADHAPURA DISTRICT
DRY ZONE
Anuradhapura
Nuwara Wewa
Nachchaduwa Tank
Hurulu Wewa
Kalpitaya
Kala Oya
PUTTALAM DISTRICT
Puttalam
Minneriya Tank
Wewa
Parakrama Samudra
KURUNEGALA DISTRICT
Maho
MATALE DISTRICT
Deduru Oya
Chilaw
Kurunegala
Matale
Horaboru Wewa
KANDY DISTRICT
Kandy
Kegalla
Negombo
COLOMBO DISTRICT
KEGALLA DISTRICT
WET ZONE
NUWARA ELIYA DISTRICT
Badulla
Nuwara Eliya
COLOMBO DISTRICT
Bandarawela
Pottuvil
Panadura
KALUTARA DISTRICT
RATNAPURA DISTRICT
Ratnapura
Wellawaya
Kalutara
Batugedara
Kalu Ganga
DISTRICT
Deniyaya
HAMBANTOTA DISTRICT
GALLE DISTRICT
MATARA DISTRICT
Wirawela Tank
Ridiyagama Tank
Hambantota
Galle
Matara
BATTICALOA DISTRICT
Batticaloa
Rukam Tank
Unnichchai Tank
Kalmunai
Senanayake Samudra
Irrakamam Tank
BADULLA DISTRICT


LAND UTILIZATION MAP OF
CEYLON
BOTANIC GARDEN
MAJOR AGRICULTURAL STN
AGRICULTURAL STATION
RESEARCH STATION
EXPERIMENT STATION
PADDY STN & PADDY FARM
PADDY SEED STATION
STATE CHENA
VEGETABLE SEED STN
TOBACCO STATION
CINCHONA STATION
ROTATIONAL FARMING SCHEME
FARM SCHOOL.
CITRUS ORCHARDS
CATTLE & ANIMAL BREEDING CENTRE
FRUIT FARM
CATTLE, BUFFALO STUD LIVESTOCK FARM
DAIRY
COTTON MULTIPLICATION STN.
KITUL TRIALS
COTTON ROTATION STN
BOARD & LODGING FARM
SUGAR CANE STATION
CASHEW PLOT
PLANT NURSERY
COLONISATION SCHEME
DRY ZONE
WET ZONE
N. P
N. C. P.
N W P
E. P
C. P
W. P.
S. A. P.
U.
V.
A.
S. P.
District Boundary
Province Boundary

LAND UTILISATION MAP OF

CEYLON

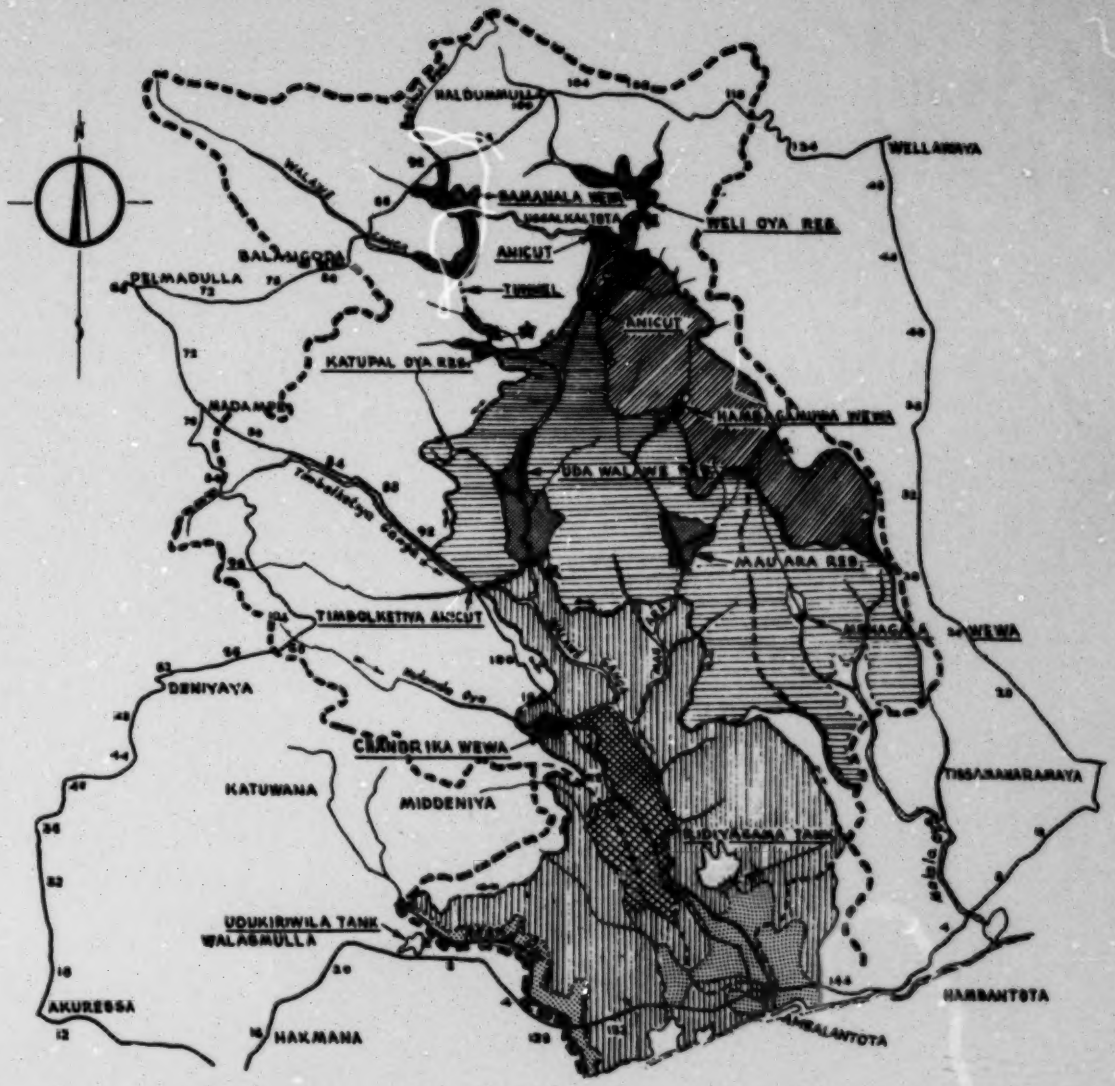
Showing areas of cultivation

(a) RUBBER and PADDY
(b) FOREST RESERVES and OTHER CULTIVATIONS
(c) TEA and COCONUT

TEA
COCONUT

FOREST RESERVES
OTHER CULTIVATIONS

CEYLON
DISTRIBUTION OF RURAL AND URBAN POPULATION
1946
EACH DOT REPRESENTS 1,000 PERSONS
250,000 PERSONS
62,500 PERSONS
DRY ZONE
WET ZONE
COLOMBO
CEYLON
RIVER BASINS
REFERENCE.
WALAWE BASIN BOUNDARY
WALAWE REGION "
WALAWE
DRY ZONE
WET ZONE
N
0 10 20 30 40 50
MILES



RESERVOIR	ACTIVE STORAGE CAPACITY AC. FT.	INSTALLED POWER	EXTENT OF IRRIGATION ACRES	LEGEND
SAMANALA WEWA	118,600	120 M.W.	38,300	
" POREDAM RES.	8,400			
KATUPAL OYA RES.	44,300			
UDAWALAWE RES.	180,000	5 M.W.	47,000	
WELI OYA RES	117,000	4 M.W.	18700	
MAU ARA RES	17,600			
CHANDRIKAWEWA	20,000		5000	
TOTAL	505700	139 M.W.	107,000	

4 3 2 1 0 4 8

MILES

WALAWE REGION DEVELOPMENT PROJECT

EXISTING DEVELOPMENTS .....

NEW RESERVOIRS SHOWN THUS .....

POWER PLANTS - 30 - -90- .....

MAIN CANAL SYSTEM .....

WALAWE REGION BOUNDARY .....

23 E - Oct.1962 - 1,500

E/CONF.39/A/12
26 Sept.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.4.2.5

Ceylon

SOLAR ENERGY FOR REFRIGERATION USING FLAT PLATE COLLECTORS

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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SOLAR ENERGY FOR REFRIGERATION USING FLAT PLATE COLLECTORS

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Introduction

1. In recent years there has been an increasing interest in the use of solar energy for providing cooling by operation of the vapour absorption refrigeration cycle. The intermittent cycle would seem to have engaged more attention[1,2,3,4,5,6] than the continuous cycle[7]. This paper attempts to evaluate the performance of commercial size units on the basis of the performance of an experimental intermittent refrigerator incorporating a flat plate collector.(The performance of the refrigerator will only be summarised here as a fuller report appears elsewhere[6].)

Experimental refrigerator and test results.

2. A simple experimental refrigerator made up of materials available locally was erected to operate on the intermittent cycle with solar energy as its only source of power, and is shown schematically in figure I. Circulation was by thermosyphon, assisted by bubble formation in the collector during regeneration. During regeneration valves VA and VB were open and valves VC and VD closed, thereby bypassing the absorber. During absorption valves VC and VD were open, and the ther two valves closed.

3. The solar energy collector consisted of a copper sheet 5 ft by 3 ft 6 in, and 0.03 in thick, painted dull black. To the plate were soldered six 1/4 in diam pipes at 6 in intervals. The ends of the 1/4 in pipes were welded into the headers. At the rear of the plate was corkboard insulation 4 in thick. There were 3 glass covers (1/8 in thick, and of commercial quality) in front of the collecting surface. The collector was inclined 24° facing due west. Figure II is a photograph of the rig.

4. The results obtained for 4 days are summarised in table 1. The 4 days were cloudless or nearly so. Regeneration took place during the hours of sunshine. Refrigeration was commenced when the solution had cooled to atmospheric temperature. During refrigeration the evaporator temperature gradually rose from the minimum value given in row 18 to about 27 °F at the end of refrigeration.

5. If a heat exchanger is provided to transfer heat from weak solution to incoming strong solution, the ratio of effective cooling to radiation received (row 23) can be increased to about 8 or 9 per cent, and the effective cooling per ft^2 of collector surface would also show a corresponding improvement - i.e. 100 btu/sq ft would be a reasonable expectation for effective cooling on a cloudless day.

Applications of the intermittent and continuous cycles.

6. Two categories may be specified: (a) applications where cooling is not required during the period of regeneration, and (b) applications where cooling is required during the period of regeneration.

7. The intermittent cycle may be considered for applications in the first category. Two examples are ice manufacture and the cooling of residential rooms at night. Test results indicate that for an iceplant using aqua-ammonia with a refrigeration capacity of 1 ton(heat abstraction of 288 000 btu per day though not continuously), about 3000 sq ft of collecting surface would be required, and prevision made in the plant for the storage of about 5000 lb of strong solution(compare row 24, table 1), and 525 lb of refrigerant.

8. For the airconditioning application the initial solution concentrations may be higher with a consequent improvement in the cycle COP. Hence for a similar refrigeration capacity of 1 ton, the area of the collecting surface and solution storage capacity would be about half that required for ice manufacture.

9. In these applications the size of the storage vessels will militate against the development of large units unless higher generator temperatures are realised by auxiliary concentrating solar collectors or fossil fuel combustion.

10. In the second category of applications - i.e. when cooling is required during the period of regeneration -- it is necessary for regeneration and absorption to proceed simultaneously. Therefore if the intermittent cycle is employed provision must be made for twice the solution storage required for an application in the first category. It seems that the continuous cycle would be more suitable here.

11. In a continuous cycle application using aqua-ammonia, a successful hermetically sealed circuit has been designed incorporating an electrically operated transfer tank to transfer solution from the absorber to the generator[8]. The use of electrical power may be avoided by providing solution reservoirs and valves to be operated manually, or better, if such can be successfully devised, a float - operated transfer tank[9].

12. For ice manufacture a 3-stage continuous cycle cascade system may be considered. This arrangement is not entirely impractical as it may be more convenient to construct the generator in 3 units since the generator heating surface(the solar collector) is so extensive. This scheme would appear to merit further investigation.

13. the continuous cycle may be also considered for room cooling, and the design of such a unit is outlined below.

Design of solar energy operated room cooler.

14. The operating conditions for the aqua-ammonia cycle were chosen as follows: strong solution leaving absorber - concentration 0.59, temperature 100 °F; weak solution leaving generator - concentration 0.495, temperature 170 °F condenser pressure 200 lbf/sq in. Assuming a thermal ratio of 0.5 for the heat exchanger in the solution circuit, the COP is obtained as 0.58.

15. The load is the cooling of an office room from 8 a.m. to 4 p.m. at the rate of 18 000 btu/h. The expected evaporator temperature is about 56 °F and

the room is to be cooled by panels in which the refrigerant evaporates. It has been estimated that 600 sq ft of collecting surface (with 2 glass covers) would be required to provide the necessary solar heat for the generator. Solution and refrigerant storage will also be incorporated so that the cooling period could over-run the regeneration period by about an hour when so required.

Conclusion

16. Even when electrical power or fossil fuel combustion makes high generator temperatures possible, the absorption refrigerator is larger than its vapour compression counter part, and its first cost is greater[9]. With solar regeneration using flat plate collectors, the absorption refrigerator becomes even bulkier - and more expensive. However, a comparison of the first costs, maintenance costs, depreciation and running costs of a solar operated refrigerator and a vapour compression unit would be interesting, particularly in a region where fossil fuels are imported and electrical power is relatively expensive.

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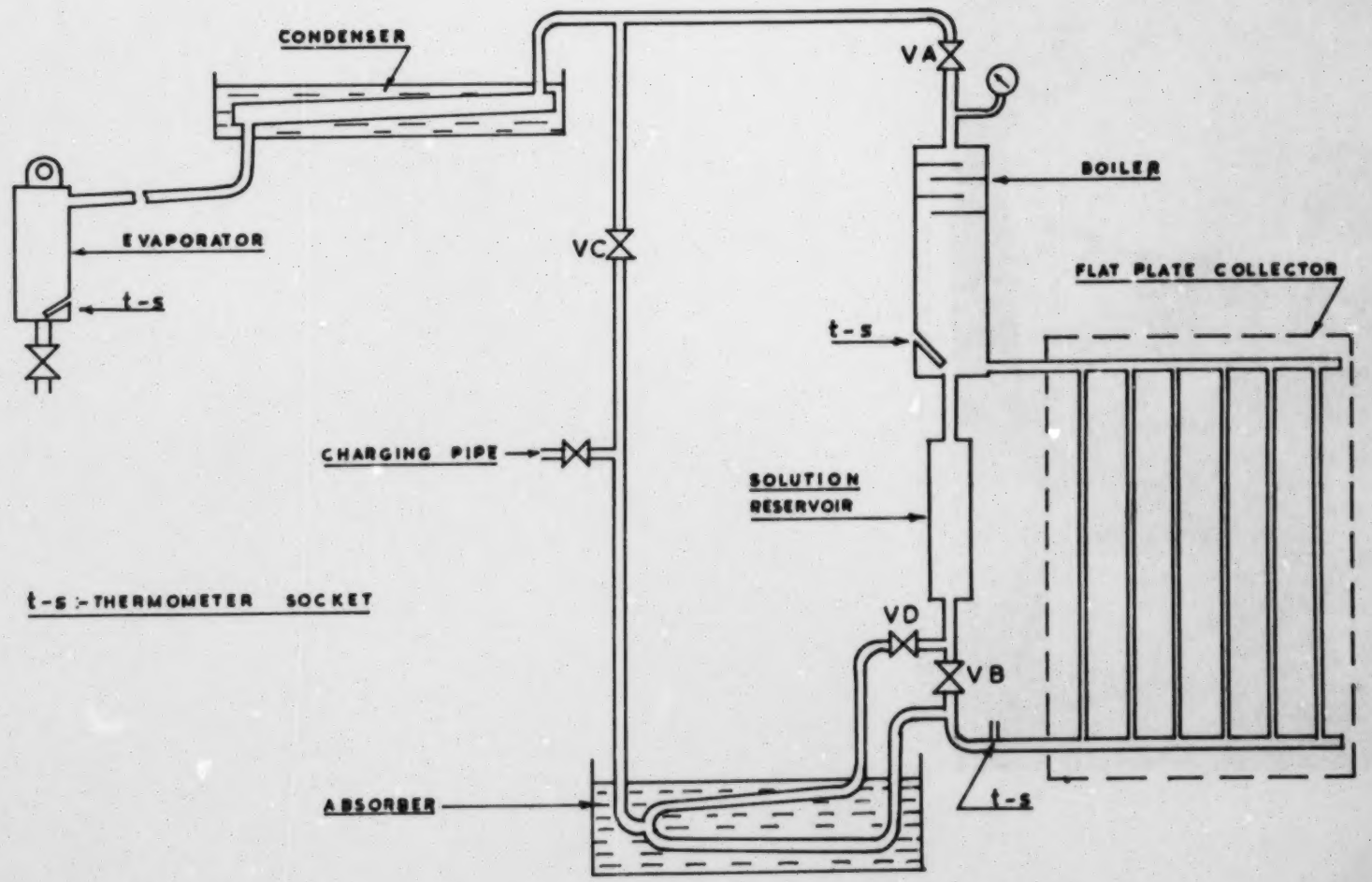
TABLE 1. Summary of Solar Refrigerator Test Results

1. Test no.	9	12	13	14
2. Date of commencement of test	13 Feb	3 Mar	6 Mar	9 Mar 1960
REGENERATION				
3. Time of starting a.m.	9-45	9-41	10-25	10-50
4. Duration	5 h	6 h 40min	5h 5 min	5h 30min
5. Initial mass of solution,lb	17.97	19.61	18.76	19.47
6. Initial temp. of solution, F	83	86	89	89
7. Initial conc.(mass fraction NH_3)	0.462	0.464	0.44	0.460
8. Maximum solution temp. °F	202.5	212	211.5	211
9. Maximum solution press. lbf/sq in	207	205	203	205
10. Final concentration	0.398	0.370	0.364	0.377
11. Mass of distillate(NH_3) lb	1.92	2.92	2.24	2.59
12. Condenser cooling water temp.°F	86-96.5	86.5-96.5	87-94.5	87-95.3
13. Atmospheric temperature °F	87-95	88-90	88-90	88-90
14. Heat received by solution and distillate(Q_s) btu	3786	4869	4220	4533
15. Total radiation received(Q_r)btu	16 671	23 576	18 900	20 022
REFRIGERATION				
16. Approximate duration h	3	6	5	5
17. Absorbing solution temp. °F	93-95	91.5-95	95-97.5	94-99
18. Minimum evaporator temp. °F	14.5	9.5	8	13
19. Total effective cooling btu	900	1360	1052	1217
20. Effective cooling per sq ft of collecting surface per day	51.4	77.8	60.2	69.5
21. Actál COP	0.238	0.279	0.249	0.268
22. Theoretical COP	0.30	0.316	0.267	0.302
23. Ratio of total effective cooling to total incident radiation %	5.4	5.8	5.6	6.0
24. Effective cooling produced per lb of strong solution btu/lb	50.1	69.4	56.1	62.5
PERCENTAGE ENERGY BALANCE DURING REGENERATION				
25. Total incident radiation (Q_r)	100	100	100	100
26. Radiation incident on collector plate (Q_{rp})	60.5	58.5	59	62
27. Increase in heat content of solution(both phases)(Q_{sh})	22	20	22.5	21.5
28. Heat absorbed by collector, solution circuit, insulation(Q_e)	15	11.5	13.5	12.5
29. Heat loss from collector plate, and solution circuit(Q_l)	23.5	27	23	28

FIGURE I SCHEMATIC DIAGRAM OF EXPERIMENTAL REFRIGERATOR



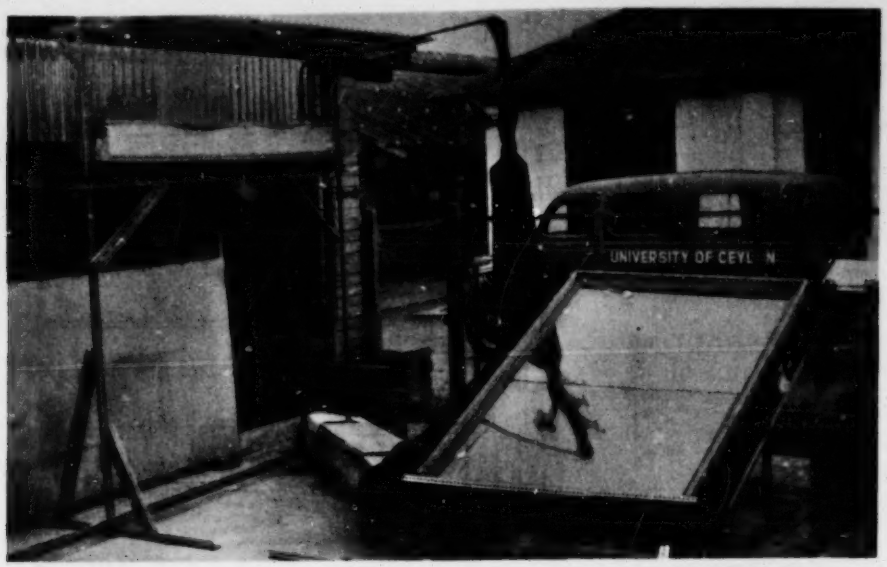


Fig. II Experimental Intermittent Refrigerator

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Agenda Item: A.4.2.2

India

BRIQUETTING OF INDIAN LIGNITES

By A. LAHIRI,
Director,
Central Fuel Research Institute Jealgora,
Dhanbad, India

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

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BRIQUETTING OF INDIAN LIGNITES

By

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Director,
Central Fuel Research Institute, Jealgora,
Dhanbad, INDIA

1. INTRODUCTION

1.1. In India lignites occur in South Arcot (Neyveli) and several other coastal regions of the southern peninsula (Travancore and Malabar), in Rajasthan (Palana), Kutch (Umarsar) and in certain parts of Kashmir. Almost all these regions do not have any known deposits of bituminous coal (there is some coal in Kashmir) and assuring supplies of energy and power in these areas for industrial and domestic uses has long been a problem. In recent years the exploitation of Indian lignites has been given the importance that it deserves and elaborate plans have been prepared for the working and efficient utilisation of the lignite deposits of South Arcot. Prior to this, lignite has been commercially mined to a limited extent in Bikaner, mainly to provide fuel for thermal power stations.

1.2. The development of the lignite of South Arcot will provide a source of fuel not only for the industries of Madras and the South in general but also for thermal stations for providing power for industries, electrification of railways, etc. This will accelerate the industrialisation of southern India. At present, hydro-electric generators are the main source of power supply in Madras State but during periods of draught there have often been drastic cuts in power supply resulting in loss of lakhs of rupees annually incurred by the industries. Cheap thermal power by utilising locally occurring lignite will form an important addition to the existing power supply system. Further, a portion of the wagons now required for coal transportation from the coalfields of the Northern India and from ports, will be released for other transport and the ports themselves will be relieved of pressure and will be able to handle more goods - both exports and imports.

1.3. The potential uses of lignite are many and varied. Lignites are, however, liable to weathering, crumbling and disintegration. In unprocessed form they can be used in boilers located near the mines, which may not always be possible because there may not be sufficient local demand for power.

1.4. Lignites have high moisture (50-60 per cent) and low calorific value (average 5,500 B.t.u./lb) and if it has to compete with bituminous coal it has to be processed and upgraded. The upgrading can be done by drying and briquetting, when it is converted into sizes and shapes suitable for handling and for withstanding transportation. At the same time the heat value is increased per unit weight.

1.5. The removal of moisture is an essential pre-requisites for the upgrading of lignite and for its industrial utilisation. The drying of lignite, however, leads to loss of coherence, and it disintegrates into powdery form on handling and transport. Briquetting of the dry lignite produces coherent shapes. Also, where long distance transport is involved, briquetted lignite can be transported at a lesser cost than high moisture raw lignite. Briqutted and carbonised lignite would be more readily acceptable as a domestic fuel because of the less smoke it produces than raw lignite. As an industrial fuel, lignite briquettes can be easily burnt in "step-grate" or "trough-grate" or even "Horizontal grate" type of boilers. They can also be burnt in normal handfired or chain-grate boilers, with certain modifications to the plant. Briquetting of lignite is achieved under pressure (10-12 tons p.s.i) and at a critical moisture, which, in the case of Indian lignites vary between 13 and 16 per cent.

1.6. Briquetting of lignite or brown coal has been operated on a large scale in Germany and other European countries as well as in Australia. In Germany and in Australia no binder is used for briquetting of lignites. Although the process of briquetting is a simple one, fairly elaborate and expensive plant is required for quantity production necessary to achieve economical costs. The successive stages are : crushing, screening, drying, cooling, pressing, dust control, steam boiler, power generation, conveying and loading.

2. WORK DONE AT CENTRAL FUEL RESEARCH INSTITUTE, INDIA

2.1. At the Central Fuel Research Institute in India investigations have been undertaken into the properties and uses of lignite, particularly from South Arcot[1-8]. Besides the usual physical and chemical analyses, much work has been done on lignite drying and briquetting, the behaviour on low temperature carbonisation, the chemical composition of the low temperature tar, the oxidation and hydrogenation of the lignite, etc. Plans for utilisation in industries have also been prepared. In the present paper will be discussed only the briquetting of lignites.

2.2. The lignites from South Arcot, Palana, and Kutch usually have between 20 to 30 per cent moisture and 6 to 16 per cent ash on air-dried basis, but the Kashmir lignites are characterised by lower moisture of about 10-12 per cent and higher ash of about 45-50 per cent on air-dried basis. (a) South Arcot Lignite: (i) The critical moisture content for briquetting remains constant (about 16.8 per cent) upto a briquetting pressure of 10 tons/sq.in. At higher pressures of the order of 16-17 tons/sq.in., the optimum moisture content decreases to 12 per cent.

(ii) The specific gravity of the briquette is maximum at the critical moisture percentage. The briquettes retain their shape during combustion. The briquettes, however, disintegrate on immersion in water. (b) Palana Lignites: (i) Palana lignites are similar in briquetting properties to South Arcot lignites in spite of slightly higher rank and ash content. The optimum moisture content is about 16-17 per cent at pressures below 10 tons/sq.in. and 12 per cent at pressures of 16-17 tons/sq. in. These briquettes burn easily retaining their shape during combustion. These briquettes also disintegrate on immersion in water. (c) Kutch Lignites: (i) These are lower in rank than the South Arcot lignite and also have somewhat higher percentage of ash (about 16 per cent on air-dried basis). The briquetting properties of Kutch lignite

are however inferior to those of South Arcot and in order to get fairly strong briquettes it would be necessary to crush the lignite to finer sizes (-72 mesh B.S.S.) before briquetting. The carbonized briquettes are somewhat stronger than the uncarbonised briquettes.

(d) Kashmir Lignites: (i) The apparent specific gravity of the briquettes was 1.4-1.5 which is high compared to the corresponding figure of 1.2 for South Arcot lignites. This might be due to the considerably higher ash content of the lignite. But in spite of the very high ash content, the briquetting properties of Kashmir lignites are similar to those of Palana and South Arcot lignites. The optimum moisture, in this case also, is 16-17 per cent at pressures below 10 tons/sq.in. but decreases to about 12 per cent at higher pressures. The strength of the briquettes is only lower than that obtained with Palana and South Arcot lignites, and like the latter they disintegrate on immersion in water. The briquettes burn with difficulty due to their high ash content and special type of combustors have to be designed for their efficient burning.

(ii) Experiments carried out on the low pressure briquetting of Kashmir lignite treated with lime water showed that these briquettes were stronger than those obtained with pitch as a binder and also have fairly good burning characteristics[9]. An explanation for the role of lime water may be found in the fact that being an electrolyte it perhaps causes the flocculation of the colloidal clay associated with the lignite and that these act as binder. Based on these investigations a full scale (10 tons/hour) plant is being installed at Srinagar for briquetting Kashmir lignite.

(iii) The effect of briquetting pressure, moisture and the presence of saw dust on the burning characteristics of Kashmir lignite briquettes were studied in a specially designed thermogravimetric balance. The results showed that the briquettes burn rapidly but that the rate can be lowered by increasing the briquetting pressure; increased moisture content raises the combustion rate. There is also a tendency for the saw dust to burn preferentially but this can be overcome by hot briquetting at 180-200°C at a pressure of 8,000 lb./sq.in.

3. CARBONIZATION OF LIGNITE BRIQUETTES[10,11]

3.1. Lignite briquettes when carbonized under normal conditions yield a powdery char. Under controlled conditions, however, particularly by regulating the rate of heating, it is possible to obtain strong briquettes.

3.2. In the laboratory experiments carried out at the Central Fuel Research Institute, briquettes were prepared at 23.67 tons/sq.in. pressure using Palana and South Arcot lignites crushed to -72 mesh B.S.S. and dried to different moisture contents. These briquettes were carbonised in a stream of nitrogen in an electrically heated furnace at different rates of heating. It was noted that (1) maximum mechanical strength was obtained by carbonising briquettes with 5-6 per cent moisture; (2) even under optimum conditions, the strength of briquettes on carbonisation was generally lower than that of raw briquettes; (3) the rate of carbonization had a great effect on the mechanical strength of the briquettes, carbonisation at 5°C/min. and below gave good briquettes; above this rate, the briquettes obtained were generally poor; (4) about 15-20% breakage occurred on carbonisation at 850°C under optimum conditions (moisture 5 per cent, rate of hea-

ting, 2°C/min.). The compression strength of the carbonised briquettes varied from 3500 to 6000 lb./sq.in.

3.3. An interesting correlation has been noted between temperature of carbonization and compression strength. The briquettes were heated at 2°C/min. in a stream of nitrogen, to the desired temperature, cooled and their compression strength determined. The strength decreased to a minimum at about 450°C and then increased with rise in temperature. From the tests carried out upto 850°C it appeared that the strength would continue to increase with further increase in carbonization temperatures.

4. ROLE OF MOISTURE AND OF RELATIVE HUMIDITY

4.1. The strength of the briquettes is significantly influenced by changes in the moisture content rather than changes in the mineral matter of the lignites[7]. The strength might be attributed to either the presence of forces of cohesion between its component particles or to the forces of adhesion between water and the surface of the component particles. The former forces are due to the interplay of the 'secondary' or 'surfaces' forces which are set up as a result of certain intramolecular rearrangements. The binding due to these forces has been also called 'true cohesion'.

4.2. If the forces of cohesion are operating in the briquette, the determining factor in the strength of the briquette would be the elastic constant of coal. This is known to change with the mineral matter content of coal. Since the lignites contain widely varying proportions of mineral matter, their elastic constants should also be different and, therefore, their briquetting properties should have been different. But the fact that the lignites exhibit similar briquetting properties, in that their strength is significantly influenced by the variation in moisture, would indicate that the strength of the briquette is largely due to the forces of adhesion. The determining factor in this case is then the adhesion energies. The adhesion energies are known to change with moisture content.

4.3. The relative humidity of the atmosphere has considerable influence on the strength of lignite briquettes[8]. Briquettes prepared at 11-17 tons/sq.in. pressure with 12.4 per cent moisture are relatively less liable to changes in relative humidity and have compression strength of 3500-4500 lb./sq.in. under adverse humidity conditions.

4.4. The weakening of the briquettes on exposure to high R.H. can be explained in terms of van der Waal forces which become dominant when the optimum moisture content in the briquette is exceeded.

5. MECHANISM OF BRIQUETTING

5.1. Investigations on the mechanism of briquetting involved in lignite were also undertaken[12]. The reactive groups present in lignite were estimated after the groups were blocked by acetylation and by barium acetate treatment. On briquetting the strength of the lignite briquettes was reduced considerably. Also, briquetting with polar and non-polar liquids showed that the strength of the lignite briquettes increased with increase in the hydrogen bonding capacity of the binder. Other evidences like the behaviour of lignite briquettes on immersion in water, the thermodynamic aspects of sorption of moisture on lignite, the physico-chemical behaviour of lignite during compression, etc.,

coupled with the above results indicate that hydrogen bonding involving both the OH and COOH groups and the "optimum moisture" are mainly responsible for imparting strength to lignite briquettes[13].

6. FERROCOKE FROM LIGNITE & MAGNETITE ORES

6.1. Studies have been carried out on the manufacture of ferrocoke from South Arcot lignite and Salem magnetite ore with a view to using it in iron and steel industry[14]. It has been found that straight blends of lignite-magnetite containing upto 15 per cent iron ore yield ferrocoke briquettes of compressive strength 1000 lb/sq.in. and 64 per cent of the ore in the briquette is reduced to metallic iron. The iron ore concentration can be doubled by mixing 10 per cent of high or low volatile coking coals without weakening the ferrocoke briquettes. The ferrocoke obtained with lignite-slaked lime-iron ore in the ratio 70:15:15 is similar in strength to that obtained with lignite-iron ore in the ratio 85:15. Increase in the concentration of slaked lime to 30 per cent adversely affects the strength of the ferrocoke.

7. INTEGRATED DEVELOPMENT OF SOUTH ARCOT LIGNITE

7.1. Based on the investigations carried out at Central Fuel Research Institute[1] and on some tests conducted in West Germany, elaborate and ambitious plans for the mining and efficient utilisation of South Arcot lignite have been prepared by the Government of India. An autonomous body, Neyveli Lignite Corporation, has been set up and the initial plans are to mine 3½ million tons of lignite per year, the method of winning being that followed in west Germany and in Australia. Of the 3½ million tons to be mined about 1½ million tons per year will be used for the generation of power in a thermal station of 250,000 kW capacity. This will be made available to the Madras Grid to supplement the power generated in the existing hydel power stations which have rather wide seasonal fluctuations as far as the load capacity is concerned. Plans have also been prepared for the establishment of a fertilizer plant to produce 152,000 tons of urea per year using about ½ million tons of lignite as the raw material. This urea plant will be among the largest in the world. The balance of the 1½ million tons of lignite per year that will be raised will be briquetted and carbonised with a view to providing smokeless fuels which will be eminently suitable for domestic consumption in place of charcoal and also for general industrial uses. Initially, about 380,000 tons of carbonised briquettes will be produced, when 43,000 tons of char dust, 6400 tons of motor spirit, 51,300 tons of tar and 1032 tons of phenol will also be obtained as by-products. The char dust can be used in the calcium carbide industry and also for the manufacture of activated carbon, carbon electrodes, etc., while the phenols would find ready use in the plastics and coal chemicals industry. During the mining operations for the removal of over-burden, excellent quality of china clay will be available. This will be washed and used for the manufacture of ceramics. The integrated lignite project of South Arcot will thus help towards relieving the acute shortage of electric power in the Madras region both for domestic and industrial uses, will provide fuel for the common man and for industry and also fertilizers for the improvement of agricultural production. Successful implementation of the project will, no doubt, help the progress of industrialization in Southern India.

7.2. Looking to the future, there is a possibility of South Arcot Lignite being used for the production of coke suitable for reduction

of iron ore in low shaft furnaces. The byproducts that will be obtained from carbonisation of the lignite can serve as starting material for the production of many chemicals and industrial intermediates. A good amount of work has also been done on the carbonisation characteristics of these lignites at the Central Fuel Research Institute. There is also a possibility of gasifying the lignite and using the gas so produced for the synthesis of liquid fuels. Useful products like Montan Wax can also be extracted from the lignite.

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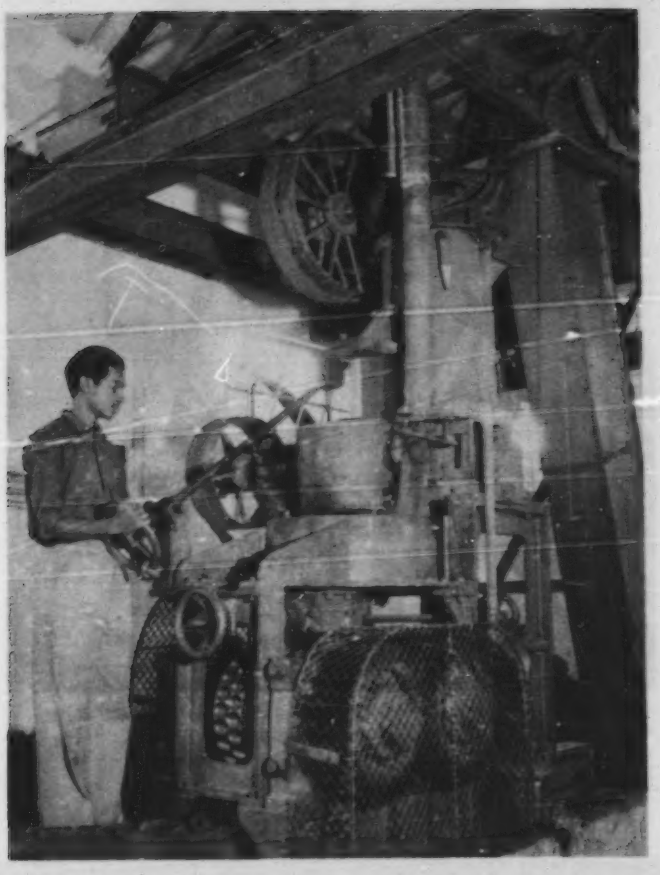

Fig. 1 - A view of the 1½ tons per hour Briquetting Plant at Central Fuel Research Institute.

Fig. 2 - Briquettes

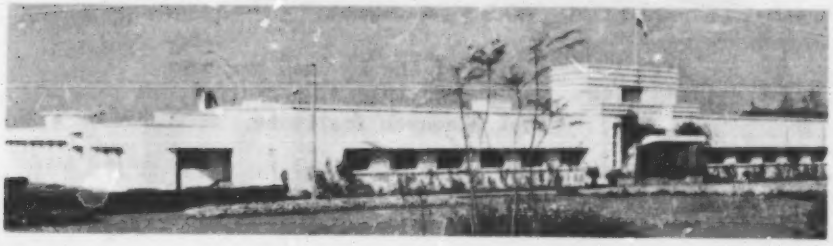

Fig. 3 - A view of the Front Building of the Central Fuel Research Institute

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Agenda Item: A.1

Ghana

MAPPING OF NORTHERN GHANA FROM AERIAL PHOTOGRAPHS

By R. J. SIMPSON, A. R. I. C. S.,
Chief Survey Officer,
Survey of Ghana

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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MAPPING OF NORTHERN GHANA FROM AERIAL PHOTOGRAPHS

Serial No.100 Sub Item A.1

by

R.J. Simpson, A.R.I.C.S., Chief Survey Officer, Survey of Ghana

1. One of the problems to be overcome in the development of Northern Ghana is the lack of adequate maps. Up to the early fifties the only maps covering some 40,000 square miles of the territory of Northern Ghana were the results of rapid military surveys at the comparatively small scales of 1/125,000 and 1/250,000 which are not only too small and inaccurate but also quite out of date for development purposes. The first attempt to improve upon the map coverage of these areas was made in 1948-50 when the Royal Air Force produced the first aerial photographs of the area.

2. As a result of the War, little had then been done in the training of surveyors and draughtsmen and several devices had to be found to overcome difficulties in the way of producing maps from aerial photographs in Ghana for the first time with the limited resources available.

3. The Directorate of Overseas Surveys very kindly loaned the Department the services of one experienced aerial survey draughtsman. First a number of hand stereoscopes and some 12" steel straight edges were procured and a 25'x25'x4" plotting board constructed by a local carpenter. The board was then sprayed with white celulose enamel and grided at the scale of 1/30,000. A machine for slotting templates and some 11"x11" sheets of acetate were next added to the equipment. Training then began with some 10 draughtsmen. In a few weeks good standards had been acquired in base-lining, template cutting and photo interpretation.

4. The next big problem was ground control. Apart from this being sparse, no surveyors could be spared to identify control in the field or provide extension to the existing controls. Pillars of the existing control traverses followed roads but were placed several feet back in the featureless bush. Such pillars could hot be identified on photographs from mere descriptions, as is often possible in the case of trigonometrical points. As controls had to be provided without recourse to field work, the following procedure was adopted for establishing a control system for both photography and master grid :-

(a) Selected co-ordinated traverse pillars were plotted on the master grid from co-ordinates.

(b) Strips of transparent plastic were placed over these points on the master grid and the positions transferred to the plastic.

(c) The plastic strips were then removed from the master grid and the traverse was then plotted between each pillar.

(d) Traversed points which could be easily identified on the photographs were marked-up and given a number.

(e) The plastic strips were then returned to the master grid, and the selected points on the plastic were pricked through to the master grid.

5. Thus with these traversed but un-co-ordinated points accurately plotted on the master grid by graphical methods, it was possible to identify these points readily on the photographs.

6. It was impossible to lay the templates according to the sheets system. Templates were laid in areas where the control was fairly plentiful. Often huge areas of templates had to be fitted to edge points arrived at from earlier lay-downs, there being no control points what-soever to work to.

7. Great care had to be taken to ensure that templates 'fell' into position without the use of the slightest degree of force. It was not expected that the accuracy of the templates assemblies would be of a standard equal to the inherent errors in the slotted template method i.e. the arithmetic mean error of points fixed by radial intersection from a template assembly. None-the-less it was expected that any inaccuracies would not be greater than would normally be tolerated on a 1/50,000 map.

8. To date, some 30,000 square miles of territory has been compiled at a scale of 1/30,000. These compilations will be photographically reduced to 1/50,000 and fair drawn at that scale for publication. Contouring is to be done by photogrammetric methods in the United Kingdom. Meanwhile, demands for planning maps in limited areas for development needs are met by using these planimetric compilations as a base for contouring by plane table methods. It has been found possible with the aid of aerial photographs and field stereoscopes to produce adequate contoured maps by these methods in about one-third the time taken to produce them by the conventional plane table methods.

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UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.3.2.2

Italy

CYCLIC CHANGES IN SOUTHERN-ITALIAN PRECIPITATION

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

INTRODUCTION

Attention was recently drawn[a,b] to the possible role which short wave radiation may bear on water-nucleating properties of some compounds which are present in the atmosphere as aerosols. A recent study by PAVESI[c] has furthermore shown that paucity of very active nuclei in clouds may often lead to considerable supersaturation and thus inhibit the precipitation of the "potentialy available" atmospheric water. On the other hand, a possible contribution of water-nucleating systems to the water cycle on an extensive scale, has been stressed by KOMABAYASI & IKEBE[d] in a recent review.

An influence of the sun on the balance of precipitation which may go further than the plain heating-evaporation process, appears therefore possible. Thus it has been reported[e] that the atmospheric content of ozone follows a periodic variation with time in accordance with the solar cycle, and it is known on the other hand that the "southern oscillation" phenomenon appears to behave similarly (cf: (e)). While not going into the details of mechanisms involved, this paper has as its object the investigation of a possible overall correlation between a parameter representative of the sunspot cycle, and the annual precipitation pertinent to a zone of a somewhat restricted geographic region.

DATA AND RESULTS.

Data on annual volumes of precipitation in Sicily and Sardinia for the period 1926 - 1943 inclusive were taken from

publications of the Hydrographic Service of the Italian Ministry of Public Works.(f) Stations were chosen with care to obtain a reasonably uniform distribution around major mountainous systems, and were subdivided into 5 distinct categories of altitude, for which precipitation averages were computed; the number of stations considered and their grouping is given in Table 1.

The results obtained are expressed in "anomalies" (percentage ratios of an annual precipitation per altitude category, to the average annual precipitation value for the period studied); or in corresponding ratios of anomalies at higher levels, to the lowest level anomaly. Since a parallel study of data pertinent to the Italian mainland, which used a much larger number of stations than the one considered in this contribution, revealed no substantial correlation of precipitation values with such various geophysical occurences as are commonly thought to be dependent on some aspects of the solar activity, and since but a small correlation with average annual temperature values seemed to be detected, we limit ourselves here to regressions of anomaly values against the annual average Zürich sunspot number. This choice furthermore appears to offer the advantage of enabling an annual precipitation trend to be computed in advance, in accordance with the pattern outlined below, since the sunspot number can be computed fairly well for future years.

Linear correlation coefficients between annual anomalies and the sunspot number, are given in Fig. 1, as function of

TABLE 1.

	Number of Stations taken at levels:						Ave.Altitude of Station level(metres)				
Category Nº	0	I	II	III	IV	Tot.	0	I	II	III	IV
level(metres)	0-200	200-500	500-700	700-1000	>1000						
SICILY	34	37	49	18	4	142	102.4	376.1	595.3	875.4	1008.5
SARDINIA	42	42	35	15	-	134	63.0	332.8	585.7	751.5	-
TOTAL	76	79	84	33	4	276	80.6	353.1	591.3	819.1	1008.5

Distribution of stations in Sicily & Sardinia according to their altitude categories.

the phase with which the Zürich number was taken with respect to the year of precipitation. The regularity of the cyclic pattern obtained appears very good despite a relatively small number of stations used. Maximum correlation seems to follow the solar parameter by about 2 - 4 years, while the minimum lies at about +1 phase for the region studied. Even greater cyclic regularity is obtained between RATIOS of anomalies at a given level of altitude, to the lowest level anomaly - and the lag, as revealed by Fig.2. The maximum correlation lies at about + 1 year phase. If linear regression parameters between anomaly ratios and the sunspot number are computed and plotted against the average altitude of the higher level, fairly consistent linear trends are obtained, as shown in Fig. 3.

CONCLUDING REMARKS

Results similar to the above, can be obtained if a larger number of stations is taken and the analysis extended to the Italian Mainland. It was noticed however that small changes in phase of curves such as the ones given in Figs. 1 - 2, may be expected from region to region. The figures quoted indicate that a general trend of natural precipitation values over a suitable zone, may in some cases be easily estimated, if sufficient previous data on volumes of precipitation are available. This in turn may be useful in both the planning and monitoring of hydrologic enterprises in a zone where long-range estimation of water level fluctuations is required. The method can furthermore be

profitably applied in evaluations of long-term cloud seeding campaigns where base values of anomaly trends are sometimes necessary for a correct estimation of an induced precipitation.

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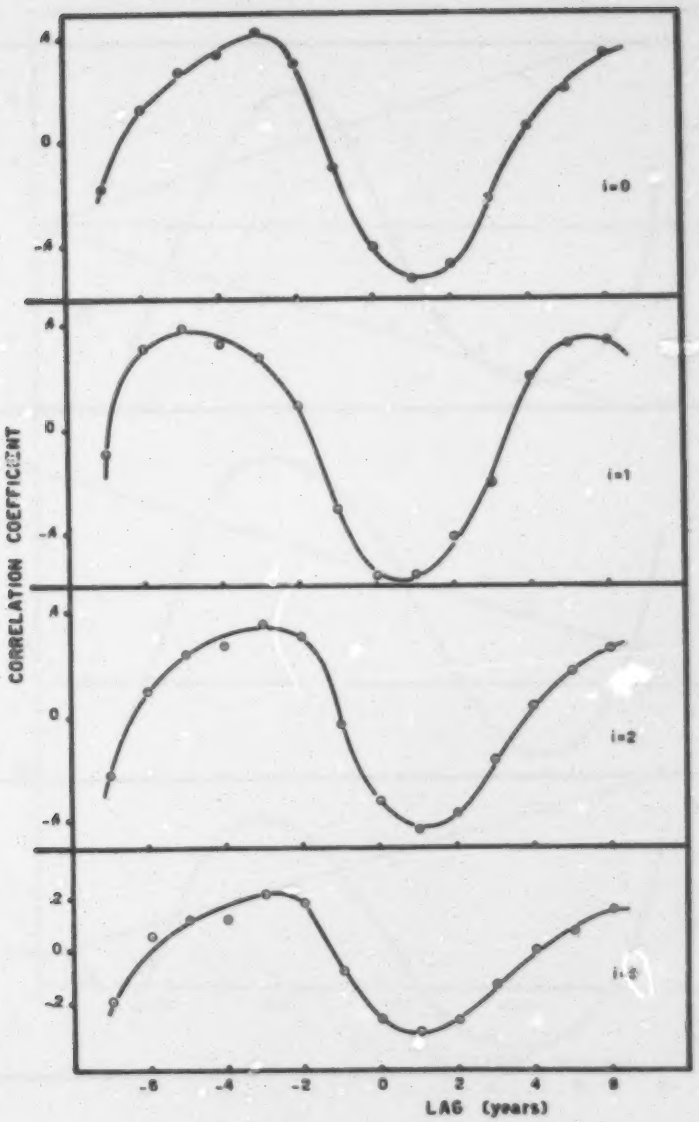

Fig. 1 - Plot of linear correlation coefficients between annual anomalies at the "i" level altitude, and the relative Zürich annual average sunspot number, with the phase, in years, by which the sunspot numbers lagged with respect to the year of anomaly computation. Values for Sicily alone were used in calculations.

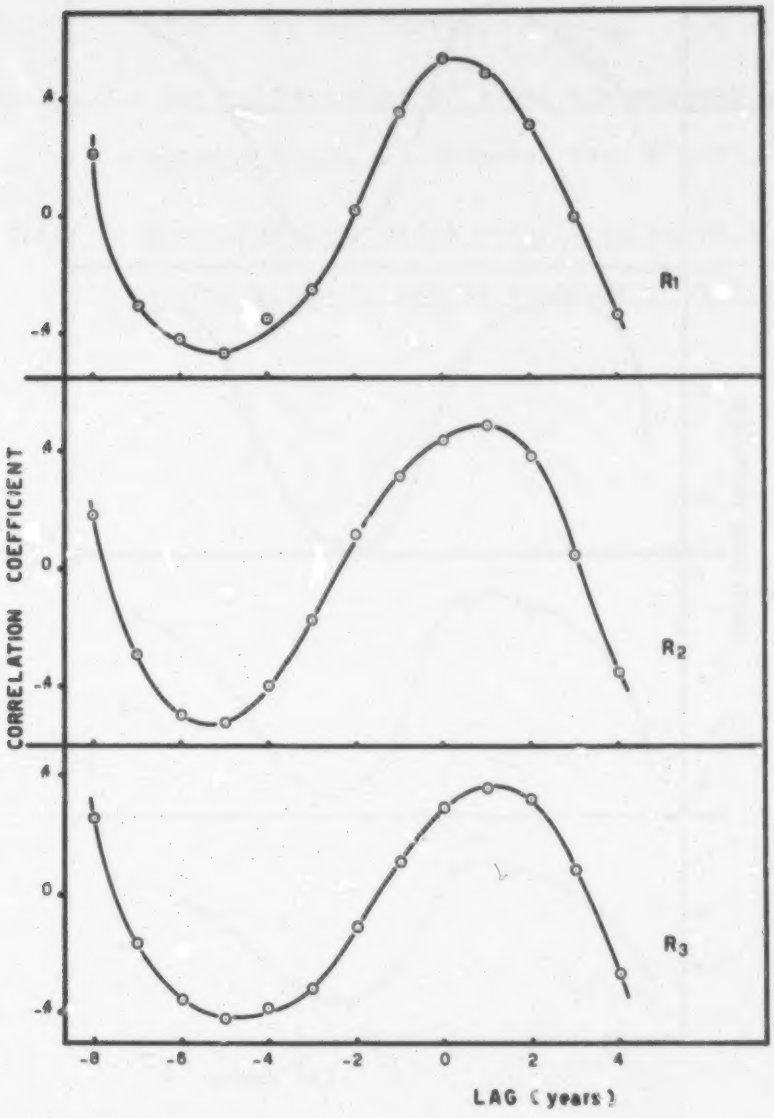

Fig. 2 - Change of linear correlation coefficients between ratios of anomalies at altitude level "i", to anomalies at level zero, and the relative Zürich annual average sunspot number, with the phase, in years, by which the sunspot numbers lagged with respect to the year of anomaly computations. Values for Sardinia alone were used in calculations.

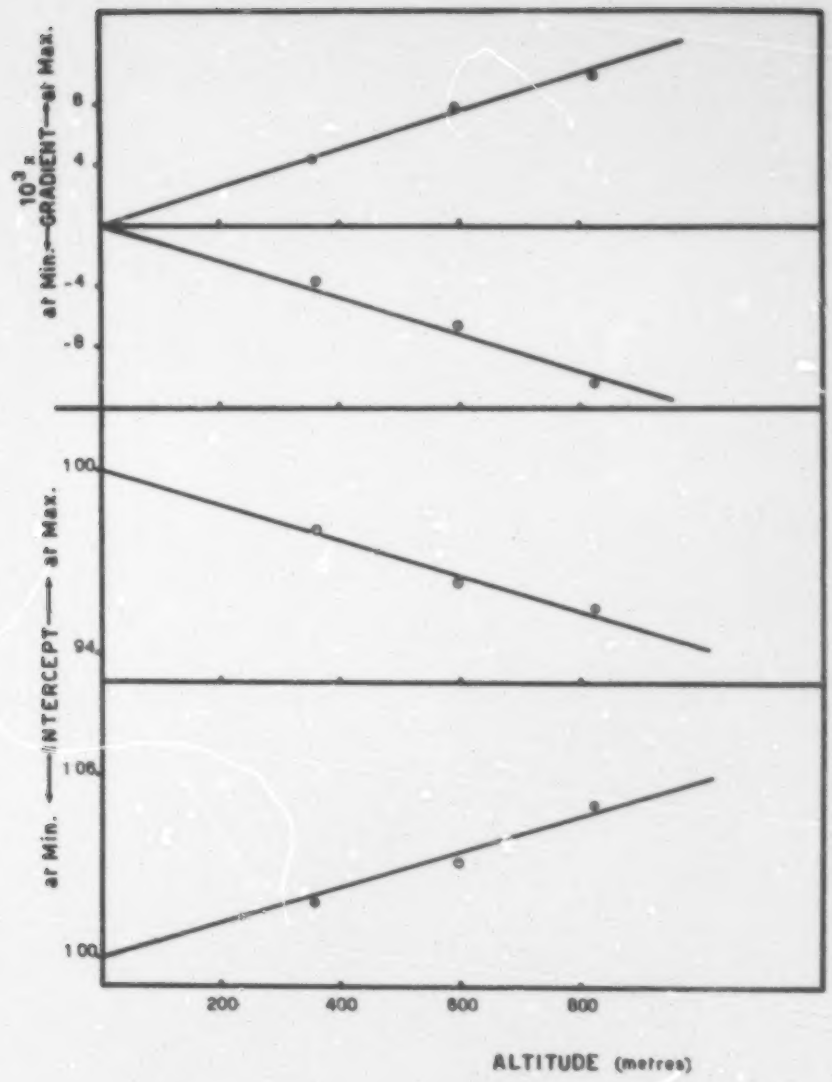

Fig. 3 - Plots of linear regression parameters computed at phase values corresponding to lag of +1 and -4 respectively (approximate maxima and minima for a cumulative diagram of the type of Fig. 2) and pertinent to the system: $Anom_i/Anom_o$ vs. Zürich annual relative sunspot number - against average altitudes of station categories studied. All values of both large Italian isles were used for this diagram. Tentative regression lines are forced through zero and unity origin values, respectively.

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